

WE PROFILE THE MOST IMPORTANT GARAGE INVENTIONS OF 2015

AUSTRALIAN

POPULAR SCIENCE



Polaroid goes square



**Or is this just a light plane you can drive home?*

DRIVE THE SKY

Is the Aeromobil the world's first genuine flying car?*

AUSTRALIA IN SPACE

Why NASA needs us, from Mars to Pluto

YOUR SMART HOME

We review the latest in home automation

EAT BUGS, SAVE THE WORLD

Could a diet of insects mean more meat for everyone?

PLUS! Why science isn't perfect • **An Aussie electric scooter** Build a G-force meter • What is the Church of Church?



MAY 2015





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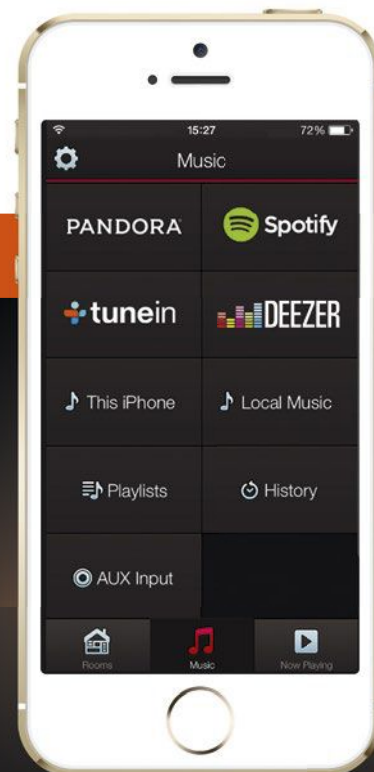
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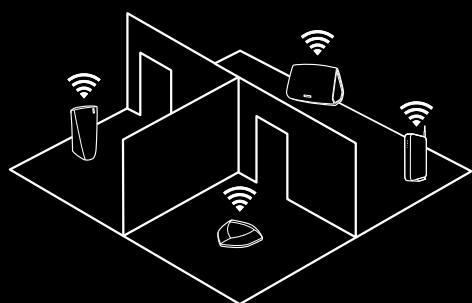
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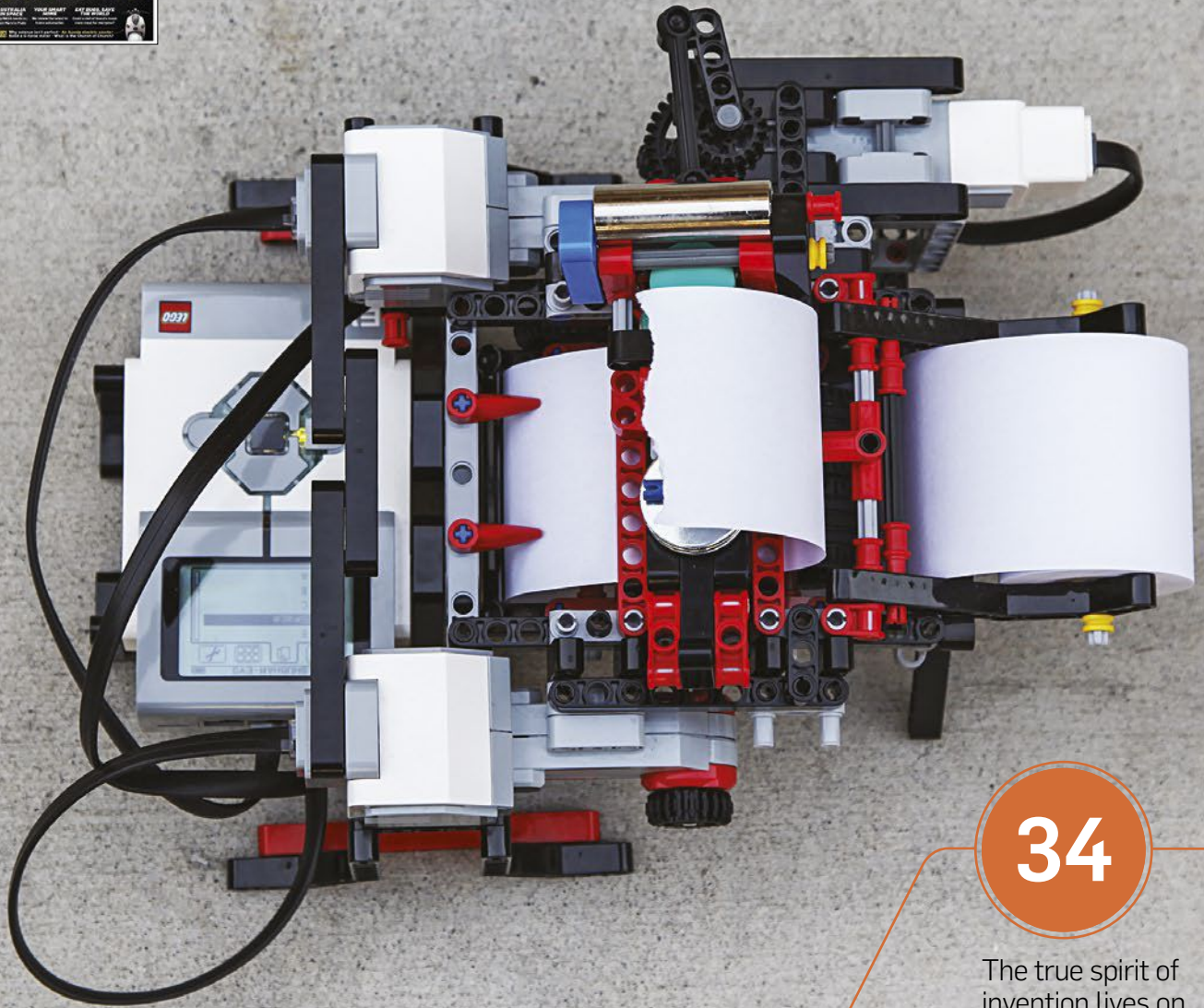


ON THE COVER

Okay so technically it's a light aircraft you can drive home (instead of keeping in an expensive leased hangar) but unlike so many other pipe-dream concept-machines, the Aeromobil has actually flown. What's more, its inventors aren't afraid to iterate and evolve their vision as new designs and materials become available.

LEADERBOARD

US Volume 286 No.5



34

The true spirit of invention lives on in the workshops, sheds and garages of the little guys. Take Shubham Banerjee's Braigo. A Braille printer that started life as a LEGO creation and just keeps getting better (while staying cheap).

22

Samsung and HTC have new mobile phones... that are slightly fancier versions of their old phones. What do designers do, now phones can do everything?

24

After 70 years of engineering, airliners simply don't crash by themselves anymore. It takes human error to create a disaster. What's the right response?

28

Materials and money aren't what's holding back the modern skyscraper. The lifts are. If we want to build really tall, we need to rethink the humble elevator.



Apple CarPlay iLX-007E



iLX-007E 7" In-Dash Receiver with Apple CarPlay



Apple CarPlay gives you an incredibly intuitive way to make calls, use Maps, listen to music, and access messages with just a word or a touch. When you connect your compatible iPhone to the iLX-007E, you can control Apple CarPlay from the 7-inch touch screen or activate Siri to minimise distractions. You'll like the clean, flat design and slim depth for easy installation. You can also use the versatile Alpine Tunelt app. iLX-007E, iPhone and Apple CarPlay — a brilliant combination.

ALPINE
Driving Mobile Media Innovation



The Hardest Job in the World

Okay so there are plenty of hardest jobs in the world - those guys who have to dislodge the "fatbergs" from major sewerage systems spring to mind - but in terms of a struggle for success, "inventor" has to be right up there.

Humans are, by our very nature, inventors. Everything we have today is an invention of some kind. That might seem trite and obvious but I think it's worth remembering. From skyscrapers to toothbrushes, doormats to stormwater inlets built right into the kerb. Concrete. Plastic garbage bags. And so on.

Each of these was conceived, sometimes by a team, often by a single person, and championed for months, years, even decades. Most inventions are initially dismissed - as impractical, uneconomic, or pointless. Every now and then, maybe only three times out of thousand, someone comes up with something that changes the world. Or at least becomes a part of everyday life.

Indeed, for inventors who are in it for the big bucks, having your invention "taken for granted" is a sort of Holy Grail. But in fact, many inventors AREN'T in it for the money. They passionately believe their... thingie... can make the world a better place.

Sometimes, the invention is super-esoteric, hard to even explain or demonstrate the point of. Take Google. Larry Page and Sergei Brin invented a new kind of Internet search

engine. People must have said, at some point: "Why do we need that? There are already lots of search engines - Yahoo, Altavista... uh...- why do we need another one?" For me, in the beginning, Google was the search engine with the nice white page and no annoying ads. That was in 1997. Flip forward a mere 18 years, and now Google is a verb. That's some serious penetration.

Meanwhile, spare a thought for the other end of the invention spectrum. I knew a guy who invented a thing called an Iron Safe. It was a sheet of heat-resistant material surrounded by a plastic container. You put the iron in the container and clipped it closed - no one would get burned by the iron. A perfectly sensible invention that he produced and made available for purchase. Of course, it wasn't especially successful and my lasting image of the iron safe was seeing hundreds of them on palettes stretching away into the gloom of his garage...

A happier story is ongoing around long-term friend of *Australian Popular Science*, Forcite. A winner of the James

Dyson Award, this helmet was intended to revolutionise law enforcement by giving police built-in communications and added protection. But a few years later and it has evolved into an alpine sports helmet - for skiing, snowboarding, snowmobiling and more - with built-in smart tech like GPS and action camera. The key here is Forcite's adaptability. Original vision for the invention not quite 100%? Adapt it.

I admire dedicated inventors enormously. It's one thing to identify a problem or a lack in this tech-saturated world. It's quite another to develop a solution and insist that your solution is valid enough to spend time, money and resources on building, marketing, distributing and eventually selling it.

Popular Science is a magazine of future technology, sure. But at heart we're also about the little guys, the garage-inventors, the builders and makers. Sometimes we spend the afternoon staring into a nuclear reactor or driving a \$100,000 electric car. But really where we want to be is the same place as you: in the back shed or workshop, with a soldering iron and a head full of great ideas.

ANTHONY FORDHAM

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POPULAR SCIENCE

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Selling points

In "Cultured Couture" [March 2015], writer Daniel Grushkin took readers inside designer Suzanne Lee's biotech lab, where she grows leather from cells.

I worked in cotton production back in the "bad old days" of weekly insecticide applications. So Grushkin's statement that "cotton farming typically uses intensive

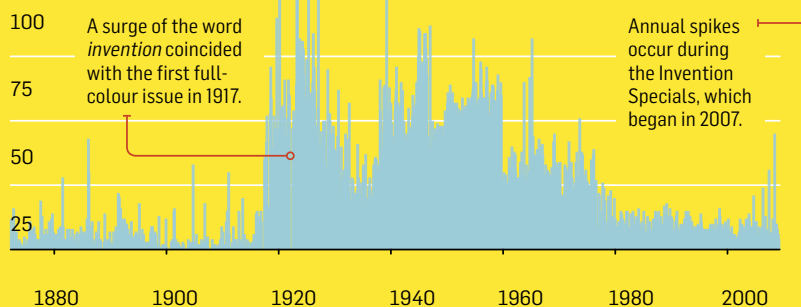
pesticides" stood out to me as stunningly out-of-date in an otherwise fascinating piece. American cotton farmers still use insecticides but nothing like in the

We Apologize ... Hitting the deadline for "The Science of Stress" [March 2015] proved a little, well, stressful. That may be why we mixed up the labels for the stress monitors. The good news is, if you noticed the error at the time, you're probably not very stressed.

A HISTORY OF INVENTION

Popular Science has been covering innovation since the magazine was founded in 1872. (This year's Invention Special starts on page 34.) Here's how often the word *invention* has appeared in our pages, either in articles or advertisements.

Appearances per issue



early 1990s. Now, they spend money on the latest insect-resistant GMO seed.

Ben Barstow

Editors' note: According to the USDA, the combined use of insecticides, herbicides, fungicides, and other pesticides on cotton fields has, in fact, remained constant since the late 1980s. Although it is true that genetically engineered cotton now enables farmers to use less insecticide, it has led to the increased application of the herbicide glyphosate.

I was particularly intrigued by the possibility of clothes that adapt to climate while reading about Suzanne Lee growing clothing. You could have the same jacket serving as a windbreaker in the spring and a parka in the winter. You could also have a shirt that brightens in the sun and darkens at night, thus regulating heat.

Douglas Benn



EXTREME TIMES... EXTREMERER MEASURES?

The Ghost is surely a nice piece of hardware but it's totally typical of the American response to anything. Got a problem? Throw military hardware. Don't ask hard questions like: why are there still pirates in this day and age? How are these pirates able to operate at all and make any kind of money? Surely the answer isn't a 2015 reimagining of World War 2 technology but something more nuanced like drones. Or less nuanced like ORBITAL LASER STRIKES! I'd sign up for that. **Greg Kalon**

Why don't the governments of the countries that are gestating these pirates foot the bill and take responsibility for stopping them? Why is it always up to the West to spend the big bucks? **Alan Herd**

HAVE A COMMENT?

Write to us at letters@popsci.com.au or to *Popular Science*
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ELEVEN WORDS THAT SPARKED A REVOLUTION

“Wait a minute, wait a minute,
you ain’t heard nothin’ yet.”

Al Jolson’s first spoken words in *The Jazz Singer* mark the first appearance of synchronized dialogue in a feature-length motion picture. Art mirrored life. Moviegoers truly hadn’t heard anything like this before. And when they did, they wanted to hear more. *The Jazz Singer* had less than two minutes of spoken dialogue. But it sparked a revolution nonetheless.



The Jazz Singer, 1927

SOUND CHANGES EVERYTHING

Pictures are pictures. Pictures with sound are transformational. That’s why *The Jazz Singer* hit Hollywood like a seismic wave. In its wake, silent films have all but disappeared.

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THE WALKMAN ~~RIDES~~ WALKS AGAIN

You probably already have a personal audio player in your pocket and two more in your bag: smartphones, tablets, iPods, and laptops can all squirt out tunes. But to the true audiophile, they're all junk (except maybe the laptop paired to a good USB DAC). Blame compressed, low-resolution sound files—great for jam-packing your hard drive with music, bad for pure sound quality. The Sony Walkman ZX2 aims to fix that.

This portable hi-fi music player is a far cry from the original Walkman that launched a million mixtapes when it debuted in 1979. The ZX2 plays just about every file type on the planet, and when it's paired with a headphone amplifier, there aren't many products that can match it for quality and tone—even Neil Young's oddly-named and shaped Ponos Player.

If you've already committed your iTunes money to a monster digital collection, don't start hitting the delete key. Sony's DSEE HX technology upgrades those compressed files so that they sound like studio-quality high resolution. Which makes them at last worthy of your \$89,000 Kharma Exquisite Galileo loudspeakers.

MICHAEL NUÑEZ



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Obsessed

(Prices are shown in US dollars... though things sure ain't what they used to be in the old exchange rate business. Add 20% and then some... deary deary me.)

LINDSEY KRATOCHWILL

1 THE INGENIOUS MR. PYKE

Writer Henry Hemming brings to life the genius of Geoffrey Pyke, an inventor and war reporter (among other things), who once convinced Winston Churchill to build an aircraft carrier out of ice. That's just one odd turn in the adventurous tale. **\$27**

2 OSPREY ATMOS AG

Osprey's new pack shoulders some of a backpacker's burden with its new 3D suspension: a layer of seamless mesh, a hip belt, a tensioned peripheral frame, and a load-balancing harness. The fit will tempt you to pack a few extra luxuries. **From \$230**

3 WIHA BI-CUT SUPER CUT

The power button on Wiha's wire and chain cutter doubles the tool's leverage by changing its pivot point. It's great for when you need to make an extra tough cut. **From \$40**

4 SUNZAPP

Developed by communications firm Klein Buendel in partnership with NOAA and the University of New Mexico, the sunZapp smartphone app uses UV light forecasts to tell you when to apply sunscreen. The catch: Advice only works if you follow it. **Free**

5 GROW

This collector's edition game imitates life. Players build a 3D

board into a tree and in the process guide its growth. To win, players fend off beetle attacks and cultivate the healthiest flowers of their colour. **\$125**

6 INTEL COMPUTE STICK

A TV can become a full-fledged PC with Intel's Compute Stick. The dongle-size device comes loaded with Windows, 2 GB of RAM, 32 GB of storage, and even a USB port. Go on, build your PowerPoint on the big screen. **\$150**

7 HUSH

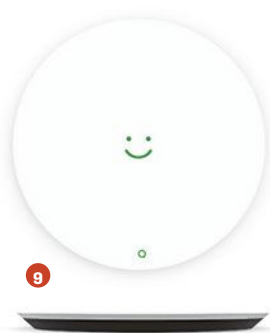
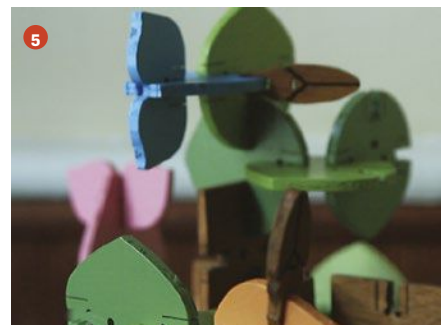
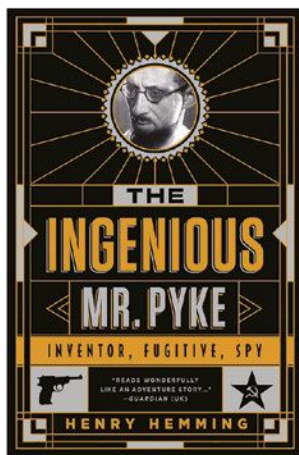
Earplugs are great for blocking out a snoring roommate or a night-owl neighbour. But they muffle important noises too. Hush earplugs use Bluetooth to send alerts when your alarm goes off or an emergency call comes through. **\$150**

8 YETI RAMBLER COLSTER

Hot summers call for cold beverages and that requires something more than a plain old foam cozy. Yeti gave the Colster double-wall insulation to vacuum-seal cool air in and a gasket to hold a cold one (or three) in place. **\$30**

9 QARDIOBASE

Weighing yourself is not often a pleasant affair. Qardio lightens the mood with its new smart scale. Among other capabilities, it presents your results in emoticons and with haptic feedback, instead of harsh, unfeeling numbers. **\$149**



10 TOMORROWLAND

Inspired by Walt Disney's vision of futurism, this sort-of-time-travel adventure follows a science-obsessed teen who stumbles into a world of technological possibility. She's met there by a former boy genius, played by George Clooney, naturally. **21 May**

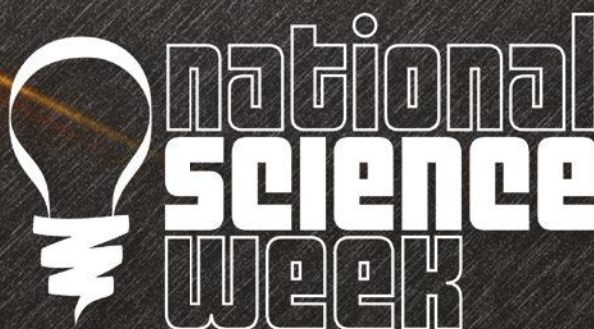


CLOCKWISE FROM TOP LEFT: COURTESY PERSEUS BOOKS; COURTESY OSPREY; COURTESY CRICKET GAMES; COURTESY QARDIO; COURTESY WALT DISNEY PICTURES; COURTESY HUSH; COURTESY YETI; COURTESY INTEL; COURTESY KLEIN BUENDEL; COURTESY WIHA



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**POPULAR
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A Megawatt Monster

↓
When it comes to manoeuvring a 320-km-per-hour racing prototype, engineers tend to hew to a long-held belief: Rear-wheel drive is better than front-wheel drive for handling and

weight distribution. Nissan's new GT-R LM Nismo may turn that notion on its head. It's the only front-wheel-drive racer in the elite LM P1 prototype class at the 24 Hours of Le Mans World Endurance Championship, which starts June 13, in the sleepy

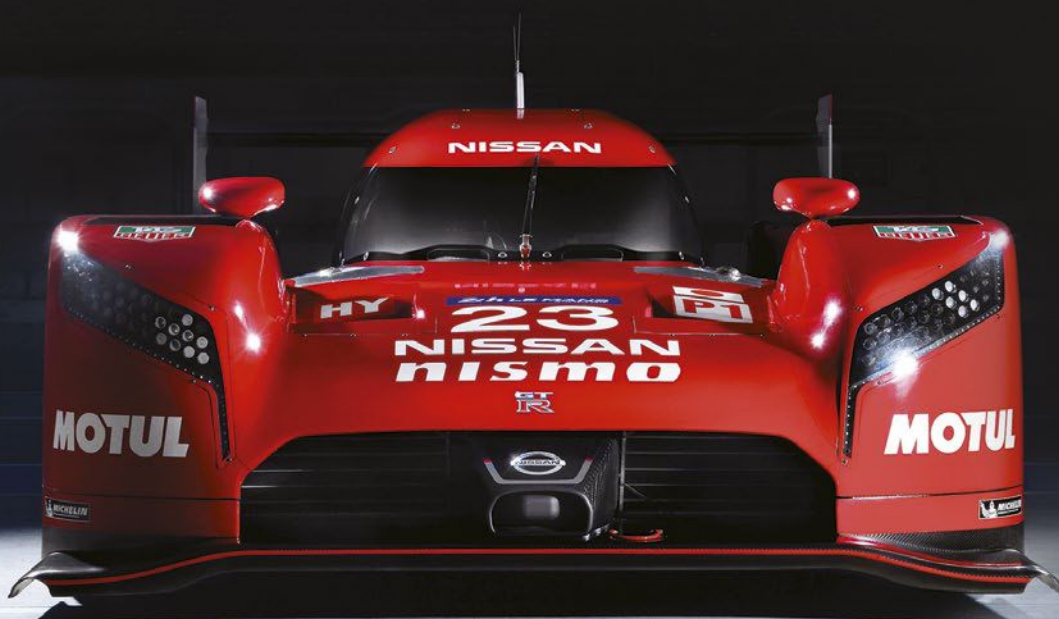
The GT-R LM Nismo's generates about 500 horsepower with its combustion engine. The ERS adds 600–700 more.

town of, well, Le Mans, France.

Nissan engineers placed the GT-R's twin-turbo V6 engine up front to shift the weight forward. It's a counterintuitive approach: Engineers typically distribute weight evenly for balanced handling. But behind the GT-R's engine sits a kinetic energy recovery system (ERS), which captures energy during braking and stores it for later use. Most teams in the LM P1 class employ ERS for added horsepower and acceleration, but Nissan's team found a clever way to exploit it.

Moving the engine forward makes the front brakes work harder. That creates more kinetic energy to harvest and could boost the car's chances of winning. But the biggest payoff could come offtrack, when Nissan applies the same technology to increase acceleration and fuel economy in its production vehicles.

MATTHEW DE PAULA



CAR NEWS YOU SHOULD CARE ABOUT

1

At the CyberAuto Challenge in February, a 14-year-old hacked a (real) car using \$15 of computer parts. The stunt, put on by spare parts maker Delphi, shows how vulnerable cars with cloud-based navigation and infotainment systems have become.

2

The United Kingdom will see the first driverless cars on public streets this year, when Oxford University begins testing a modified Nissan Leaf. The move puts the UK ahead of the US (and us), where public testing remains tangled in red tape.

3

The Intelligent Damage Detection System being developed by German parts supplier Hella uses small piezoelectric sensors placed behind car body panels. The sensors generate an electric charge under pressure, indicating when the vehicle's shell takes damage.

4

Spare parts supplier Continental is building an augmented reality app to guide mechanics through problems. The tablet app connects wirelessly to a car and walks a user through diagnosis and repair. Continental expects the tool to be available in late 2016.

DESIGN OF THE MONTH



Bentley EXP 10 Speed 6

This two-seat concept car heralds big change for Bentley, especially after two years of incremental improvements. It's a reinterpretation of Bentley's traditional styling—though from this angle it looks like an Aston Martin—and modernises the cockpit with a high-resolution touchscreen. It also uses new manufacturing techniques, such as 3D metal printing, for the front grille mesh, exhaust pipes, and door handles.

450

Number of kilometres (approx) that the 2017 Audi R8 e-Tron electric sports car can run on fully charged batteries, more than double the range of the previous R8 e-Tron

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The Platform

HOW PEBBLE'S CEO PLANS TO WIN THE SMARTWATCH WARS

EDITED AND CONDENSED BY LINDSEY KRATOCHWILL

Long before Apple shouldered its way into the smartwatch business, a little company called Pebble made a big splash—and set a \$10-million Kickstarter record—by debuting an intelligent timepiece that provides emails, texts, and music controls. Pebble Time, its newest iteration, ships this month and builds on the original with a colour display and a built-in mic. But after Apple's gorilla(glass)-sized entry into the market, can Pebble stand its ground? Eric Migicovsky, the company's founder and CEO, has some advice for his new competitors.



Popular Science: First things first. Why did you make crowdfunding and open source part of your strategy?

Eric Migicovsky: We were a small company—only five people. When we launched, on Kickstarter, people all over the world pumped our tiny project up to a scale we had never imagined. But more important, they spotted a product area that was completely new. No one was talking about smartwatches in 2012, except for these people. Our users gave us immense feedback, helped show what was working, what wasn't. That guided us and directly influenced what Pebble Time is.

PS: You must have some worries about competition from Apple.

EM: We focus on something no one else in the world focuses on. If you look at the original Apple announcement, it shows a screen with a clock in the centre and apps surrounding it. That struck me as another home screen I have to manage. We've learned that

"I THINK OUR ATTITUDE IS A LITTLE DIFFERENT. THIS IS LITERALLY ALL WE DO. WE MAKE PEBBLE."



A low-wattage reflective LCD display gives Pebble Time a week-long battery life.

apps are not the correct paradigm or correct interaction model to use on your wrist.

PS: So do you have advice for them?

EM: Oh, definitely. We learned people like using a watch as a watch. They want something durable that they don't have to treat carefully like a smartphone. The future of smartwatches is not siloed apps on your wrist. The future of smartwatches is a blended timeline that lets you see what's coming up next at a glance. That's what Pebble's Timeline software does.

PS: What are some of the trade-offs for smartwatch wearers?

EM: It doesn't replace your phone, first off. You can't make calls from our watch. Though, when you think about it, that's not what a watch should do. You have a phone for that. What a watch does is tell time, and that's the way it's been for the last 100 years. We've added this extra layer of context alongside time. Because 0800h means something different for different people. And Pebble Time helps you get information that's personal to you, that's important to you, throughout your day.

49

Number of hours it took Pebble Time to raise its first US\$1 million on Kickstarter



PS: What do you think the future holds for smartwatches?

EM: We're in the early days of smartwatches. But I'm excited about the future. If you looked at smartphones in 2007, would you have predicted things like Uber? Spotify? Instagram? We're at the same point with Pebble, where we're doing these crazy things that people love, but there's so much opportunity. 

PS: Here's a slightly cute question: how has wearing a smartwatch changed your life?

EM: I've been wearing a smartwatch for five years; it's become incredibly intertwined with how I work. I rarely take out my phone to check emails. If something important comes through, I see it. But more than anything, it allows me to relax and know that I have something else that's helping me get stuff done.

PS: Whose watch did you wear before you developed Pebble?

EM: The funny thing is, I didn't actually wear a watch before starting a smartwatch company.

Timeline

YOU OWE YOUR DAILY ROUTINE TO THE WORLD'S FAIR



Begun in 1851, the World's Fair once served as an open showroom for technical oddities, scientific breakthroughs, and cultural mash-ups. Although it still draws millions of visitors every five years, upstarts like the Consumer Electronics Show and Apple's special media events have long since eclipsed the World Fair's role in breaking tech news. Today, the fair focuses on global challenges: This year's Expo 2015, which starts on the 1st of May, in Milan, Italy, will confront world hunger. Yet, it's the World's Fairs past that still define our lives now; they exposed people to technologies that at the time seemed bizarre and futuristic—but today seem quite familiar. **AMANDA GREEN**

8 A.M.

Tuck into a carb-heavy breakfast of **Shredded Wheat**, created by inventor Henry Perky, or, if there's a chill in the air, **Cream of Wheat**, invented by miller Tom Amidon. These cereal-aisle staples both debuted at the World's Columbian Exposition in 1893 in Chicago.

9 A.M.

Tune in to *The Today Show*, courtesy of RCA. The now defunct company pioneered the **first television broadcast** at the 1939 New York World's Fair, streaming live footage of Franklin Delano Roosevelt on its early TV, called the TRK-12 (for its vast 12-inch tube screen).

11 A.M.

Plug in your laptop at your desk after a meeting and think of inventor Harvey Hubbell. He debuted the **detachable plug** at the 1904 Louisiana Purchase Exposition in St. Louis. Before that, you hard-wired devices to live post terminals—time-consuming and dangerous.

2 P.M.

Send your brother a photo of a vintage sports car in the street via MMS, and remind him that Bell Labs demoed the **Picturephone** at the 1964 New York World's Fair. Huge lines formed to use its tiny screen and push-button phone to see and talk to visitors at Disneyland in California.

4 P.M.

Kill some time playing Candy Crush Saga on your smartphone, courtesy of Former Oak Ridge National Laboratory scientist Sam Hurst. He wowed the 1982 World's Fair in Knoxville, Tennessee, with a curved-glass **touch-screen technology** he later called Accutouch.

7 P.M.

Find a date on OkCupid. **Computer hook-ups** go back to the 1964 New York World's Fair. Parker Pens connected 1.2 million fairgoers to pen pals around the globe with a computer that matched ages and interests. It had hoped to spur lifelong friendships (and pen sales).

10 P.M.

Head to an **IMAX theater** with your date to see *Tomorrowland*. The format first captivated moviegoers at Expo '70 in Osaka, Japan, with the 17-minute IMAX-ready *Tiger Child*. Don't forget the **popcorn**, first popularized at the 1901 Pan-American Exposition in Buffalo, New York.

AUDI TT

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Interface



A DIGITAL DASHBOARD THAT SIMPLIFIES THE CAR

Jump into the 2015 Audi TT and, before you turn on the ignition, you'll be struck by the simplicity of the cabin. In these days of big-screen entertainment and nav systems, the centre console feels oddly empty. There are just three AC vents, a few buttons and a lonely volume knob down near the gear selector.

That's because the TT uses a completely digital dash. It's a large, wide-aspect LCD display, tucked deep into a trad pinnacle, tricked up to look a little like the familiar two-pod instrument cluster of the average sports car.

And sure, other cars have used these virtual dashboards in place of mechanical dials before. But the TT's dash morphs and changes wildly, depending on your preference.

By default, tachometer and speedometer are in their familiar places, with basic trip computer info in between them. But select navigation (either via a button at the jog wheel near the gear selector or via steering-wheel controls) and the entire background of the dash becomes a map. Tapping the "view" button on the wheel shrinks the dials into the corners: you can still read the speed easily, but the map takes up most of the space.

Further fiddling gives access to vehicle settings, in-car entertainment, and hands-free telephone too. The Bluetooth system is set up to "automatically" pair with any phone that's discoverable (you still need to give the car permission to pair) and of course there's voice dialling

and other functions.

In practise the system took some getting used to, because we're conditioned for all that gubbins to be in the centre console. For at least the first hour or so, I kept glancing to the middle and reaching for buttons that just weren't there.

Eventually though, having everything front and centre became second nature. A lack of dedicated buttons made selecting some things - like the "exceed a set speed" alarm - a little tedious to

get to, but overall the system is simpler than the average smartphone.

At the moment, the TT remains a fairly pricey little runabout that's certainly not for everyone. But the dashboard tech showcased here is surely destined to trickle down into almost every car over the next decade. After all, it has fewer moving parts and is likely to ultimately be cheaper to mass-produce than all those fiddly little needles we've lived with for so long.

ANTHONY FORDHAM



It's easy to forget that all cars had a screen-free centre console just a few years ago. Today, it's a novelty.



1 POLAROID CUBE

Price \$150
Max video resolution 1920x1080 at 30fps
Max photo resolution 6 megapixels
Max storage 32GB MicroSD
Battery life 90 minutes
Best for Tween summer-camp filmmakers who like one-button recording

2 SONY 4K ACTION CAMERA X1000V

Price \$600
Max video resolution 1920x1080 at 60fps
Max photo resolution 8.8 megapixels
Storage capacity 16GB Memory Stick Micro (Mark 2)
Battery life 60 minutes
Best for Mums and dads who don't mind fewer mounts but want great video

3 GOPRO HERO4 BLACK

Price \$700
Max video resolution 3840x2160 at 30fps
Max photo resolution 12 megapixels
Max storage 64GB MicroSD
Battery life 60 minutes
Best for Adrenaline fiends who need the most durable—and most expensive—mount collection



TINY, RUGGED CAMERAS FOR EVERY PURPOSE

First intended for BASE jumpers, mountain bikers, and skateboarders seeking YouTube glory in crisp HD video, action cameras have grown way beyond their original purpose. Compact and lightweight, they have become an unexpected favourite among daily commuters, casual hikers, and even parents feeding their kids, all looking to capture modest—but, to them, memorable—moments.

As the usage range has broadened, so have the cameras' functions. Sony

recently upped its game with a 4K cam. Polaroid put new durable mounts on its most inexpensive model. And GoPro, the category leader with about 13.7 million cameras sold in six years, installed a faster processor and increased high-definition shooting speed from 15 frames per second to 30. Whether you're a daredevil looking for hi-res glory and crash-proof durability or a lifelogger demonstrating wine-tasting skills, there's an action camera for you. **MICHAEL NUÑEZ**

A Swiss Army Keyring*



As technologists, we take a stand against keys in general here at *Australian Popular Science*. In a world full of GPS-located NFC smart devices it seems ridiculous that we still have to get into our houses with bits of carved metal.

The good news is that our cars are moving away from keys in favour of "keyless entry". But we still have to live with them at home, so let's make the best of a bad lot. Enter the OrbitKey, a textbook example of a "why didn't I think of that?" invention that turns an ungainly bunch of keys into a neat little package that works

like a folding penknife.

Slide keys onto the hub and they fold away under a strap. There's some neat design in the way the hub has a locking system to prevent it from coming unscrewed in your pocket, but really this is good, simple design.

I was surprised how much easier it is to select the right key, even when the keys are just stacked randomly. There's room for a bottle opener or a custom 8GB thumbdrive, and a "D ring" (not shown) on the outside lets you attach awkward objects like a car remote or my stupid garage key that doesn't have a circular hole. Handy! **ANTHONY FORDHAM**

OrbitKey

\$29.95

Leather strap

Hub locking mechanism

D-ring for remotes

and odd keys

Matching 8GB USB

thumbdrive

www.orbitkey.com



FLEXING HEAD GIVES A CLOSER SHAVE

Working on the assumption that we haven't all turned into hipsters and started growing luxuriantly ironic beards, Philips continues to develop its range of electric shavers. The Shaver Series 9000 has an eight-way flexing head and claims 20% more trimmage per swipe.

My testing found that, like an older three-blade Philips unit I had on hand, a few errant bristles still refused to submit, but overall the shave does indeed feel closer.

Cleverly, the shaver works wet or dry, so hipsters can still apply ironic hipster shaving oils before trimming their luxuriant beards. This leaves the distinct smell that makes everyone think they did it with a real, ivory-handled straight-razor.

While the Shaver Series 9000 spans a number of models, the high end units like this one include a cleaning station which rinses, dries and lubricates the shaver in about 10 minutes. So you'd want to do that AFTER shaving, not before.

Lacking the fold-out trimmer of previous units, the 9000's entire head clips off, and is replaced with an included trimmer. This gives better trimming power at the expense of having to not lose the attachment in the festering junk-zone beneath the average gentleman's sink.

ANTHONY FORDHAM

Philips Shaver Series 9000

\$450 (as tested)

8-way flexing shave head

V-Track precision blades

Works with gel/foam

Clip-on trimmer attachment

Cleaning station

www.philips.com.au/grooming

*not affiliated with the actual Swiss army. Or Victorinox either, actually. Did you know they made swimwear too? Madness.

DRESSED
FOR
SUCCESS!

IN 2015, SMART-PHONES CAN'T RELY ON BRAINS ALONE

Ah, it's **flagship** smartphone season again. Every year the usual suspects release new models and we're left poring over spec sheets to figure out exactly how the new phones differ from the old.

Until this year, smartphones have mostly been about packing more and more features into the handset. Cameras, front-facing cameras, near-field communications, 4G, more memory, higher resolution screens... and all those software enhancements that most of us will never use. S beam? Is that still a thing?

As physical objects though, most smartphones - with perhaps the exception of Apple and Sony - have been, if not exactly "plasticky" in a negative sense, then certainly made of plastic. Form has very much taken a back seat to function.

For 2015, the major players know they have to up their game, which is why the top phones from Samsung (the Galaxy S6 and S6 Edge, pictured right) and HTC (the One M9, pictured left) take the physical construction of the handset to the next level.

Samsung, until now the champion of plastic in the name of removable batteries and expandable memory, has moved to sealed Gorilla Glass front-and-back for the S6, and a fancy but possibly pointless edge-curved screen for the S6 Edge. HTC, meanwhile, uses a single piece of milled aluminium for the front of the phone and a "unique" two-tone metal case for the back. The company says it takes 300 minutes

on the line to assemble *each* One M9. That's an eternity in the world of consumer electronics manufacturing. And the camera lenses are protected by watchmaker-grade sapphire crystal.

Yes, both handsets feel considerably sturdier than their predecessors (though the HTC One M9 is more an evolution of the M8). These phones cost upwards of \$1000 outright, but for the first time in a couple of years the handsets actually *feel* expensive.

Of course this kind of strategy is nothing new to Apple or Sony. The iPhone has always been a premium device, and Sony's Xperia line has pushed high-grade construction for the last couple of generations.

The reason for this shift? The increased capability of new smartphones is now iterative, rather than revolutionary. Most of us got

to grips with the convenience and speed of 4G last year - there's no big boost in download speeds to sell this year. We've come to expect 14 megapixels and more from our phone cameras, backed by a huge range of apps and software to tweak the photos. These new phone cameras meet expectations, rather than take things to the next level. Camera improvements for 2015 are those that only photographers appreciate: faster low-light performance, wider (virtual) aperture and shutter speed settings.

As for the screen - and after all, a smartphone handset is just a substrate and local processing node for a display - further increases in pixel density and overall resolution are noticed only by people with extremely keen eyesight.

The Samsung Galaxy S6 and HTC One M9 are very snazzy phones indeed. Worth throwing out your existing 4G handset? Only if you're sick of the scuffed plastic back, broken camera shield and scratched display.

ANTHONY FORDHAM



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Is it time to ban pilots from the cockpit?

COLUMN BY ANTHONY FORDHAM

The horrific events surrounding the crash of Germanwings flight 4U9525 are, in the very truest sense of the word, unthinkable. But they highlight one of the central truths in civil aviation: aircraft don't crash. Pilots crash aircraft.

The vast majority of incidents, both in the air and on the ground, are of course not deliberate. But they are due to some kind of pilot error. Occasionally, they are due to air traffic control error. And even more rarely, they are due to a maintenance error. Those are all the same kind of error though: human error.

Nervous fliers often ask things like: what if the wings falls off? What if an engine explodes? What if severe turbulence causes the plane to crash? But the history of aviation accidents - stretching all the way back to the end of WW2 - show that these machines are superbly engineered and built strong. Stronger than strong. With a few unfortunate exceptions, an airliner will not break due to bad design.

Following the deliberate destruction of flight 4U9525, there were various calls from various places demanding that the number of humans in the cockpit at all times be increased to a minimum of two. In most cases, in smaller aircraft, this is impractical, even dangerous, and actual pilots said so. But maybe the thinking is the wrong way around. Maybe there should be FEWER humans at the controls.

Time and time again, following another accident, we hear "the pilots incorrectly interpreted this" or "overrode the flight computer on that" or "erroneously changed the setting on the other".

Asiana Airlines Flight 214, which suffered a massive tailstrike on approach to San Francisco in 2013 and won the dubious honour of being the first 777 flight to cause fatalities, crashed due to pilot error. Garuda Indonesia Flight 200, which killed

AT THE END OF THE DAY, CIVILISATION ONLY WORKS BECAUSE THE MAJORITY OF US DON'T GO NUTS AND KILL EACH OTHER

or severely injured so many Australians including journalists and diplomatic staff, crashed due to pilot error. The Tenerife disaster, where two 747s collided and killed 583 people, the most ever, was due to a shocking collapse of communication between two aircraft and traffic control. Human error again.

All airliners flying today have sophisticated autopilot systems proven over millions - indeed, billions - of kilometres flown. They have GPS, auto-land systems, redundant sensors and "reflexes" millions of times faster than any human. Why do we persist in letting human pilots second-guess these machines?

The answer is simple. The overwhelming majority of pilots are excellent at their job. In larger aircraft, overlapping crews provide multileveled expertise in a vast number of complex systems. The machines work yes, but they don't *care*. Humans care. And as the history of aviation also shows, in the extremely unlikely event critical systems do fail, it's the humans that can bring a crippled aircraft home.

The Germanwings crash is a terrible entry in our proud history of flight, and it just reminds us that at the end of the day, civilisation only works because the majority of us don't go nuts and kill each other. Yes, every time you drive, you could commit mass-murder with just a little bit of effort. But even though others have, you don't. Banning you from driving your car - or making a cabin attendant sit next to a co-pilot thinking "is he trying to kill us all?" while the captain takes a wee - just doesn't make sense. ^{P/s}



Anthony Fordham is the editor of *Australian Popular Science*. If you sit next to him on a plane, expect to hear him mutter "c'mon guys, flaps four" on final approach. Because he doesn't know how to fly a plane.

2

of the 52 Boeing 747 "hull loss" (destruction of aircraft) incidents NOT directly caused by pilot error, terrorism or improper maintenance.

1502

number of Boeing 747s delivered since 1968.

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2x 72v 24aH Battery

1 Hour 80% Quick Charge

Price: From \$4490

www.fonzarelli.co



Want the latest electric technology wrapped in retro Italian style? Of course you do. From the outside it's not immediately obvious this scooter is electric – it looks like just another Vespa clone. The controls are all in the normal spots and the learning curve for existing riders is zero.

Before our ride, the Fonzarelli team warned us that the 3kW electric motor has more kick than expected, so go easy on the throttle. So of course we wrung its neck and were suitably impressed by the virtually silent 0-60 KM/H time of six seconds. It's very zippy and thanks to the immediate throttle response, more fun to ride than any other scooter we've tried.

For the boy/girl-racer inside, the scooter also has a misnamed but still fun turbo button, which gives a brief burst of extra

power for overtaking.

The Fonzarelli uses a 24Ah 72V battery that can give up 75km range, or you can slot in a second for up to 150km between charges. Like a car, the scooter uses regenerative braking to help boost the battery charge. The top speed is 80 km/h, so keep off the motorway. To charge, you actually remove the battery, which is around the size of a laptop and sits under the seat. It reaches 80% charge in just an hour, while a full charge takes 3-5 hours.

While you need a motorbike license to ride it in NSW and VIC, in other Australian states the scooter can be speed limited and ridden with a car license. The Fonzarelli costs around the same as a decent petrol scooter, so if you want to go electric, it's well worth a test ride. **LINDSAY HANDMER**

>10

Number
of Vespa
scooters, in
millions, sold
since the
1950s

BE GLAD THESE TEETH ARE ACTUALLY REALLY SMALL



Spider silk had a good run as nature's strongest biomaterial. But recently, limpet teeth—made of mineral nanofibres—were found to be up to five times stronger. Asa Barber, an engineering professor at the University of Portsmouth in England, measured the stretching force needed to break the aquatic snail's teeth and says they're comparable to human-made carbon fibre, only more flexible. "We can take these features we see in nature into the lab," he says, "to help drive better designs for planes and cars." **JUNNIE KWON**



Teeth barely longer than the diameter of a human hair allow limpets to scrape food from rocks.

A Lift That Will Reshape Skylines

With the debut of passenger elevators some 150 years ago, cities were forever changed. Freed from the tyranny of stairwells, architects built as high as they liked. That is, until they ran into another barrier: the weight of steel cables. A new elevator design from German company ThyssenKrupp may solve that problem by trading cables for tracks that employ magnetic levitation, or maglev. Unconstrained by a linear pulley system, the lifts—to be tested in Germany next year—will travel higher and in new directions, moving horizontally and even diagonally. The system, called Multi, may help make possible buildings of unprecedented size and energy efficiency, like this conceptual Edison Tower.

Patrick Bass, CEO of ThyssenKrupp North America, says supertall, power-producing skyscrapers could help accommodate booming urbanisation and finally make real that ultimate expression of science-fiction architecture: the arcology.

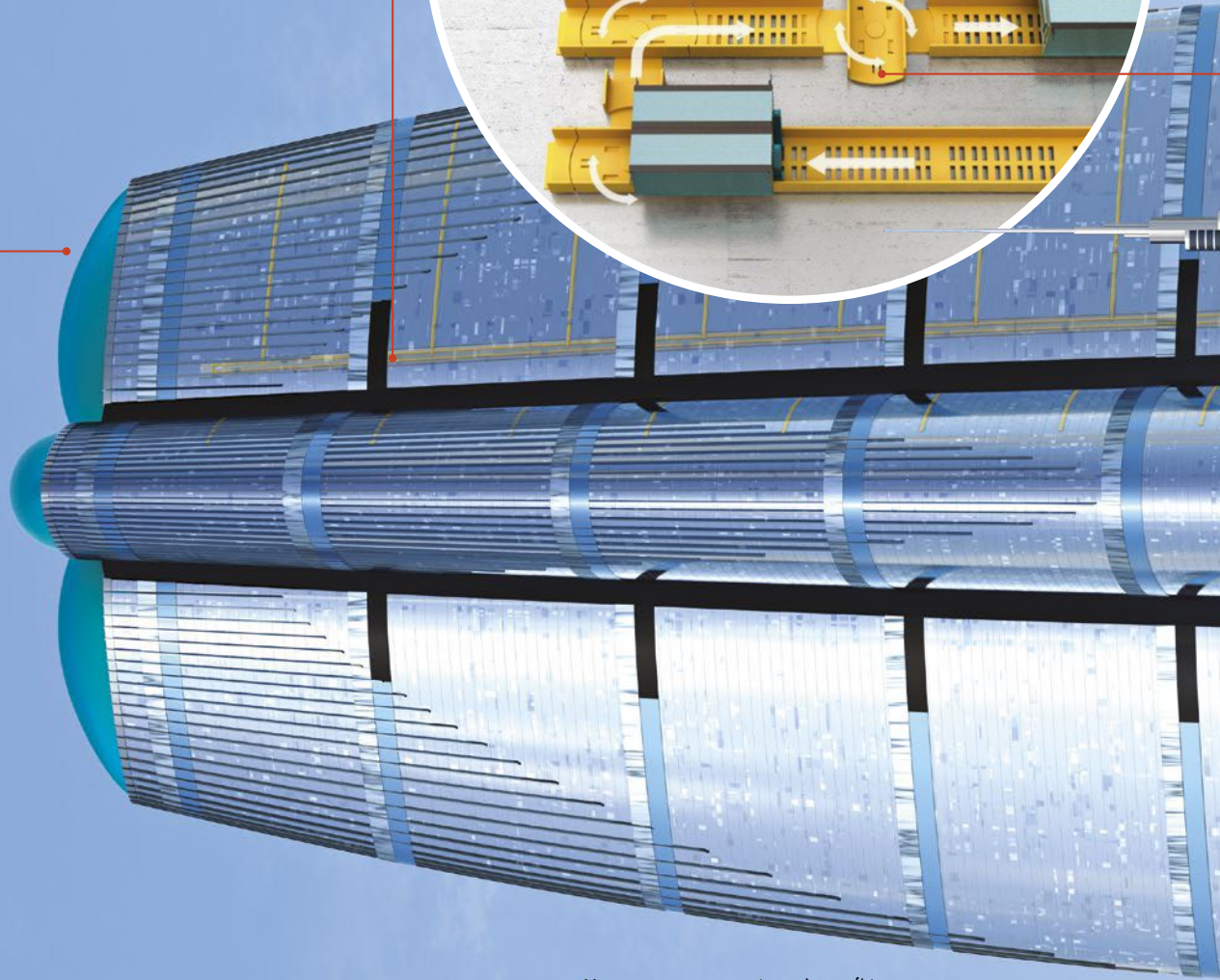
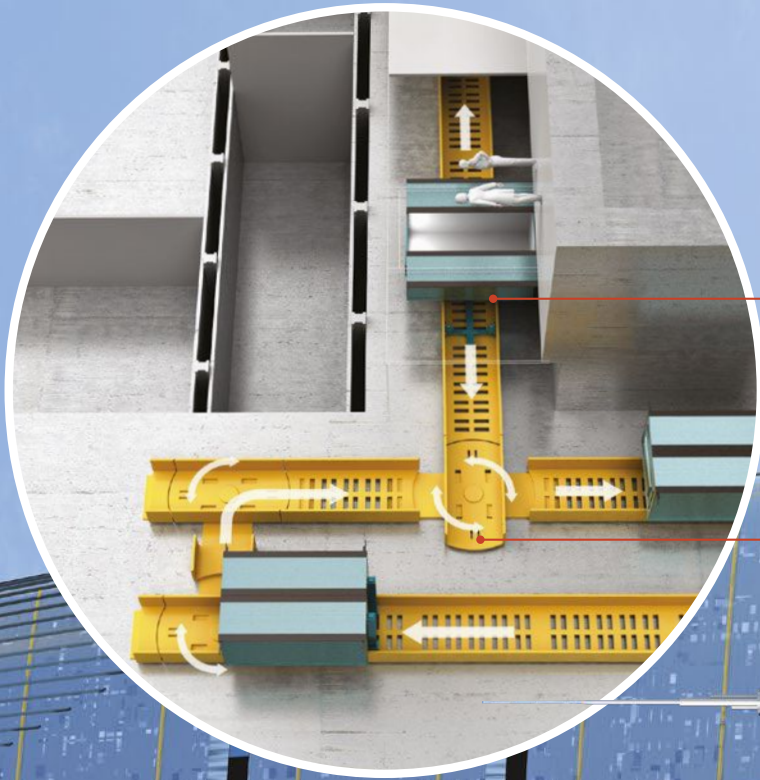
LOREN GRUSH

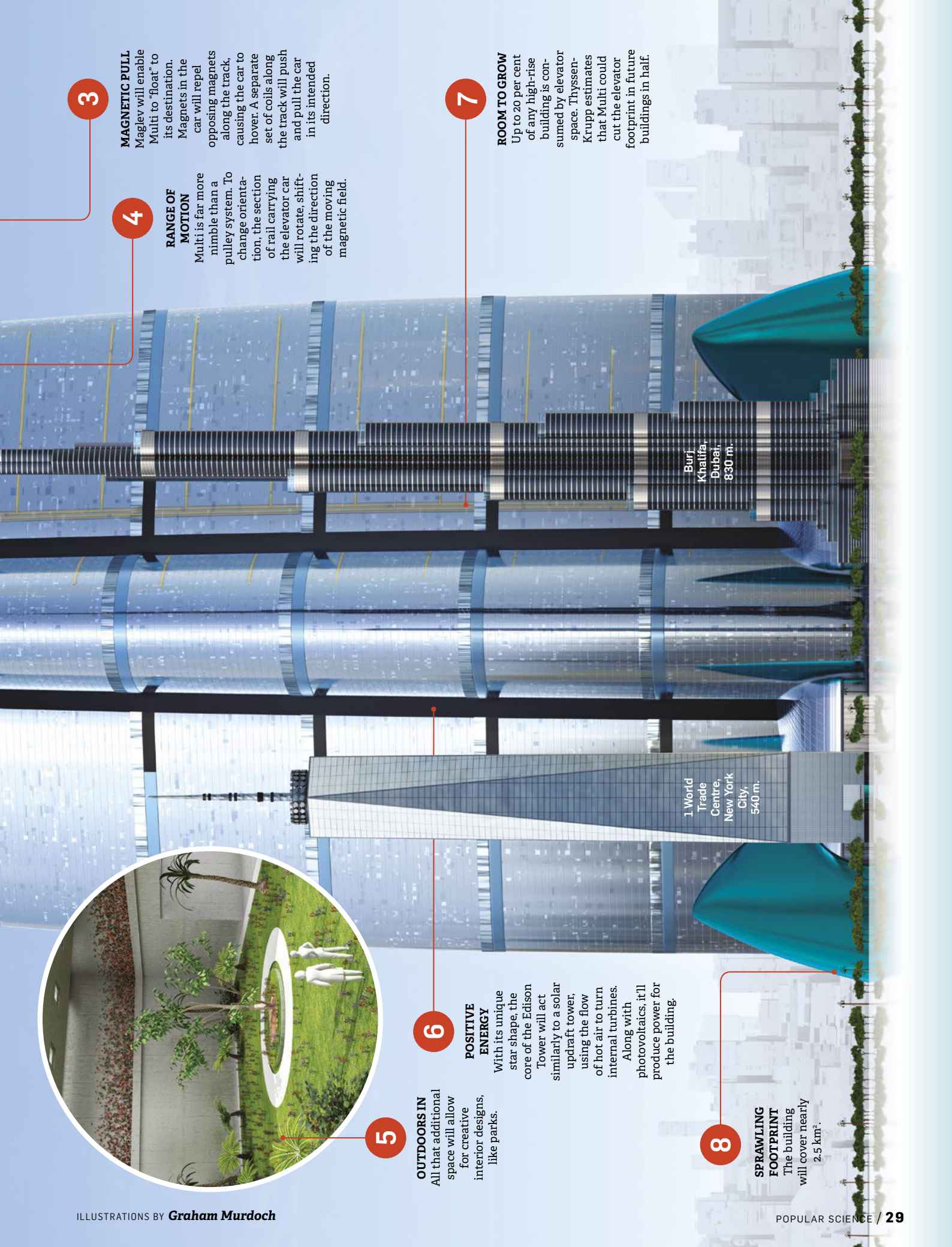
1

LOFTY DESIGN
The Edison Tower, dreamed up by German developer Frank Jendrusch, will reach nearly 1,300 metres—or as we prefer 1.3 km! The idea is to create an all-in-one space with residences, offices, shopping, and recreation. Jendrusch aims to build the tower by 2030.

2

TOPPING OUT
After about 600 metres, the cables in a standard lift can't support both the car and their own weight, so passengers must switch to a new one. Multi will run 1,300 m. direct from ground floor to top deck.





3

MAGNETIC PULL

Multi will enable its destination. Magnets in the car will repel opposing magnets along the track, causing the car to hover. A separate set of coils along the track will push and pull the car in its intended direction.

4

RANGE OF MOTION

Multi is far more nimble than a pulley system. To change orientation, the section of rail carrying the elevator car will rotate, shifting the direction of the moving magnetic field.

7

ROOM TO GROW

Up to 20 per cent of any high-rise building is consumed by elevator space. Thyssen-Krupp estimates that Multi could cut the elevator footprint in future buildings in half.



5

OUTDOORS IN

All that additional space will allow for creative interior designs, like parks.

6

POSITIVE ENERGY

With its unique star shape, the core of the Edison Tower will act similarly to a solar updraft tower, using the flow of hot air to turn internal turbines. Along with photovoltaics, it'll produce power for the building.

8

SPRAWLING FOOTPRINT

The building will cover nearly 2.5 km².

1 World Trade Centre, New York City, 540 m.

Burj Khalifa, Dubai, 830 m.

By the Numbers

CRAFT BEER IS HOGGING THE HOPS SUPPLY

↓

These days, even the skankiest pub's tap list will tell you: The craft beer boom is upon us. In 2014, the US was home to 3,200 craft breweries; this year, a new one will open every 16 hours. The trend is a boon for adventurous drinkers, but it's stretching the hop supply annoyingly thin.

"The demand is unprecedented," says Steve Miller, hops specialist at Cornell University. Hops consumption has nearly quadrupled in the past decade, thanks in part to the popularity of super-hoppy India Pale Ales, which now account for more than a fifth of the craft beer market.

Washington's Yakima Valley, a hopspot, sorry HOTspot, for domestic hops producers, can't keep up, so single-acre operations - grr, HOP operations - are popping up on other types of farms across the US. Growers in New York, Minnesota, and Colorado provide local brewers with hops that reflect a distinctive regional terroir. In return, many brewers agree to share up-front costs, guaranteeing a market for the harvest.

"The locavore movement has gone beyond the salad bowl to the pint glass," says Tom Britz, founder of Glacier Hops Ranch, which supplies 18 Montana breweries. This new, more diverse model may buoy the rapid rise of craft breweries. And a sustainable supply of pumpkin peach ale is something we can all drink to. **MATT GILES**

132

Number of hops varieties used by craft brewers, up from 88 in 2009

POUNDS OF HOPS USED BY US CRAFT BREWERS ANNUALLY

31 MILLION (PROJECTED) IN 2015

27 MILLION IN 2014

"Craft brewing is sucking up every pound of hops in the US. Growers can't expand fast enough."

—Doug MacKinnon, former director of the Hop Growers of America

6 MILLION IN 2007

Jess Peláez

On blueprinting Earth's ecosystems



Restoring environments after human intrusion or natural disasters is complicated: There's still much we don't know about the interplay of microbes and mammals, aquifers and air pollution. But geologist Jess Peláez thinks the solution is as simple (and as complex) as cataloguing all of our ecosystems, one at a time.

"We want to hand off this project to the next generation—like a seed bank for environments."



“

When humans extract resources like trees and coal, repairing the damage is often limited to 'Let's throw some dirt in a hole.' That's partly what inspired me to start the nonprofit Blueprint Earth. We want to lay the groundwork for a much higher standard. Even though we understand that everything in nature is interconnected, science has become so specialised that no one really knows how to put a complete environment back together. The goal is to combine the work being done in individual disciplines—from the granular to the macro level.

In our first project, we're working with scientists, engineers, and students to catalogue one square kilometre of the Mojave Desert. We're creating a blueprint of the geology, biology, hydrology, and atmosphere to understand how they all interact. Once we've mapped the data, we'll test our blueprint by re-creating that section of desert—the spring, the toads, the fungi—in a giant warehouse nearby. The know-how exists; scientists are already simulating geologic features, like landslides and lava flows, in labs. We're never going to be quite as good as Earth itself, but let's figure out how close is close enough.

The initial purpose is to make something functional. Take a place damaged by deforestation, like Haiti. We could blueprint an analogous area of the Dominican Republic, which is healthy, and try to replicate it in Haiti to help the environment heal in a way that isn't possible now.

Further down the road, we hope our data will be useful for space exploration and help programs like NASA and SpaceX do optimised terra-engineering. Something this big-picture can seem terrifying, but when it's framed as a collaboration over many lifetimes, it's not."

AS TOLD TO KATHERINE KORNEI

7,500,000

Estimated number of hectares world-wide lost annually to deforestation

IS IT TIME FOR US TO PHONE E.T.?

In our search for extraterrestrial intelligence (SETI), we humans have mostly just waited, and listened, for aliens to contact us. But in February, policymakers, philosophers, futurists, and astronomers convened to debate a new approach: contacting aliens directly.

Initiating active SETI is no small decision. Sure, we've tacked messages onto the occasional space probe, but transmitting detectable signals to habitable zones hundreds of light-years away requires commitment. Operating the Arecibo telescope's radar for a year would run up a \$2 million bill; future, more powerful broadcasters will suck up even more energy. Plus, we may signal for thousands of years before we reach anyone, and it could take just as long to get a response.

Some astronomers fear announcing our existence may attract the attention of civilisations bent on exploiting Earth for its resources. It's a point Stephen Hawking has argued before: "Advanced aliens would perhaps become nomads, looking to conquer and colonise whatever planets they can reach." John Gertz, former chairman of

the board at the SETI Institute, suggests banning contact altogether. "You're going to risk the entire fate of the planet just to get a conversation going?" he asks.

The fact is, TV and radio transmissions have long been leaking into space, weakly pointing to life on Earth. We don't know whether life is even out there, let alone whether it wields laser blasters. Adam Korbitz, an attorney specializing in SETI, argues there could be more danger in remaining a wallflower: "Our long-term survival may depend on joining the galactic club." Advanced civilisations might have engineered a way out of climate change or cracked the code on quantum physics.

If we hold off, we may miss an opportunity to understand the mysteries of the universe—or at least learn that we're not alone. It's time we make the first move.

SARAH SCOLES

HOW WE COULD TALK TO ALIENS TODAY

1 Blast a laser that will outshine the sun for a nanosecond so it can't be missed.

2 Broadcast the whole Internet, which is redundant enough to be self-decoding.

3 Ping habitable planets with powerful and targeted (but content-free) radio beacons.

4 Compose messages of electromagnetic waves that are intelligent, if unintelligible.



SLIM CHIPS BREED EVEN SLIMMER NOTEBOOKS

Tablet too limited and laptop too bulky? Try this new generation of ultra-slim notebooks. Packing Intel's Core M CPU tech, they run silent, cool and pack a real punch when it comes to number-crunching power. **BY LINDSAY HANDMER**



1

ASUS ZenBook X305

At just 12mm thick, the X305 features the totally fanless Core M CPU and up to a 512GB SSD. It also has a 13.3" QHD 3200x1800 (or 1920 x 1080) screen and has 3x USB 3.0 and HDMI output. The ZenBook also promises up to 10 hours of battery life. **Price: From \$1299**

2

Apple 12" Macbook

The new 12" Macbook is just 13.1mm thick, weighs 0.92KG and uses the fanless Intel Core M CPU to give a nine-hour battery life. It features a 12" 2304 x 1440 screen and up to 8GB of RAM with a 512GB SSD. In a bold move, the Macbook replaces all ports (including charging) with a single USB C connection. **Price: \$1799 - \$2199**

3

Dell XPS 13

Using a new infinity display, Dell has all but done away with the screen bezel and built something remarkable in the new XPS 13. Aside from looking great, the laptop squeezes a 13.3" screen into an ultraportable 11" frame. It's also just 15mm thick (300mm wide and 200mm deep) and thanks to the carbon fibre and aluminium body, weighs 1.18 kg.

Depending on model, you can get a 3200 x 1800 touchscreen, Core i7 CPU, 8GB, 256GB SSD, 2x USB 3.0, mini DisplayPort, SD card reader and a 3.5mm audio jack. We tested the slightly lower spec Core i5 model, with a 1080P non touchscreen – as this version promises the very highest battery life. Rated at 15 hours, the XPS 13 can indeed actually manage that.

Under a heavier load workload (think video and picture editing), you can still expect 10 to 12 hours of runtime. The higher spec model does tax the battery more, but 12 hours of light duty and 9 or more of heavy duty is nothing to complain about. **Price: \$1499 - \$2498.99**

THE 2015 **Invention Awards**

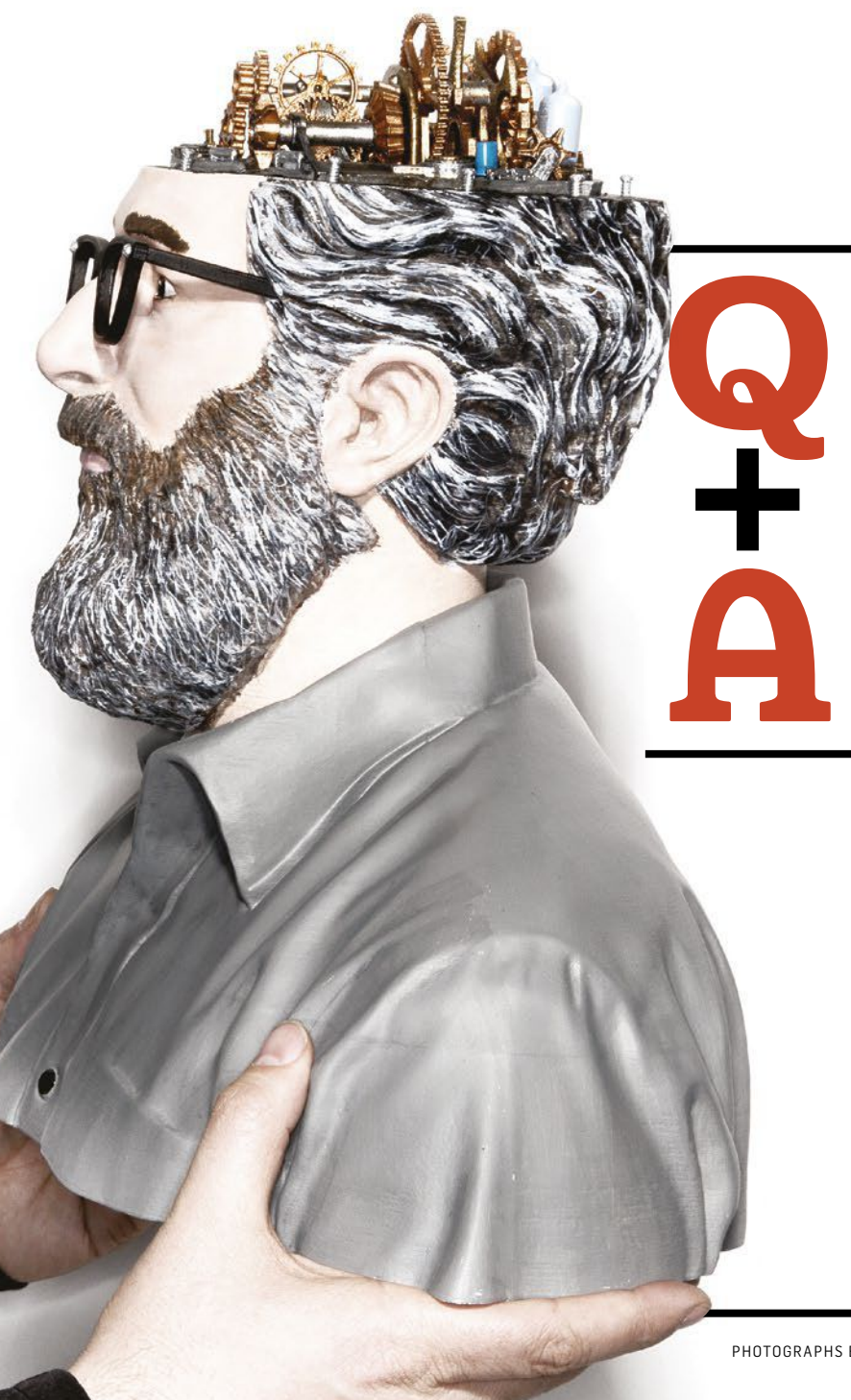


It took a whole team to build a 3D portrait of Bre Pettis. Artist Sophie Kahn scanned his head. Then, MakerBot designers Nathan Worth, Lane Feuer, and Anne Miner cleaned up the scans and digitally modelled a mechanical brain. Finally, they printed the parts on a MakerBot Replicator Z18, painted them, and assembled Pettis' plastic double. Why? Because they could.



How to Be a (Brilliant) Inventor

WITH BRE PETTIS



As the co-founder of MakerBot Industries, Bre Pettis launched the first affordable 3D printer, bringing the power of rapid prototyping and micro-manufacture into homes and workshops around the globe. While the rest of us catch up, Pettis has already moved on. At Bold Machines, the skunkworks he founded, he helps other inventors bring ideas to life. Pettis explains why invention has never been easier.

How did you come up with MakerBot?

We wanted a 3D printer, but we couldn't get our hands on one. So we just had to try and try again until we made one that worked. The core of innovation is trial and error. Fail as many times as it takes, and be strategic about what you learn.

What makes an invention groundbreaking?

So many inventions are solutions for problems that don't exist. Actual innovation is really hard, because you have to project yourself into a future that hasn't been invented yet. And often, when you think of something that changes the paradigm or is disruptive, there are all sorts of reasons you shouldn't do it. You have to stick your fingers in your ears and pretend those reasons don't exist.

How do you know whether you'll succeed?

Maybe you don't! That's why it is, in general, a horrible idea to be an inventor. You have to be willing to risk years of your life.

Do you recommend working with others?

There are a few different variations of inventor. Are

you an entrepreneur? An engineer? A researcher? A visionary? I think you need all those things on your team to actually get an invention invented and out in the world. Or you can be a couple of people wearing multiple hats.

What kind of inventor are you?

I'm a little bit of a weirdo. My primary mission is to empower people to be creative. I wish I could say I was a brilliant technical mind, but my real superpower is being a visionary and gathering together exceptionally talented people who get wonderful things done.

It sounds difficult to create something truly new, at least for those of us without superpowers.

It has never been a better time to invent things. It used to be you had to be a tycoon with a factory and a big R&D department. Now, basically anybody can buy a Raspberry Pi or a micro-controller and a bunch of sensors and be on their way. Then, when you have to add code, you can probably modify somebody else's. The software is accessible. And the Internet—there are so many things that people have shared that you can take inspiration from and modify and mess with. We live in a much more connected, fantastic, collaborative world today.

If you could give aspiring inventors one task, what would it be?

Begin.

And then what?

Don't stop.

EDITED & CONDENSED BY
SOPHIE BUSHWICK

AVIATION

A Plane That Folds Into a Car



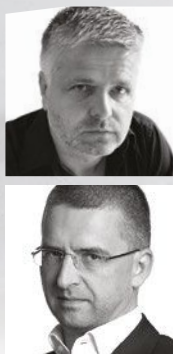
- 1** The adjustable wing can optimise its angle of attack for taking off or cruising. This allows for reduced speed and distance during takeoff.



After Czechoslovakia's communist regime fell in 1989, designer Štefan Klein began working on a concept for a flying car. Inspired by his newfound freedom, he aimed to translate that personal liberty to the skies. In 2010, he shared his work with his friend Juraj Vaculík, an entrepreneur. They joined forces to found AeroMobil and develop a viable commercial product. "We wanted to create a car and aeroplane without compromises," Vaculík says, "to provide individuals with a new, interesting option for door-to-door personal transportation."

Others have attempted and failed to build flying cars. But AeroMobil isn't a car that can fly; it's an aeroplane that can drive. Its light weight, collapsible wings, and efficient design make it precision-tuned for flight. On the ground, it provides roadster-like handling.

Last October, Klein drove the



Inventors:
Štefan Klein and
Juraj Vaculík

Company:
AeroMobil

Invention:
AeroMobil

Development cost to date:
Undisclosed

Maturity:
◆◆◆◆◆

2

Light materials, including a carbon-composite body over a steel airframe and two-kilo carbon wheels, keep weight low.

3

The prototype's 75-kilowatt four-cylinder Rotax 912 engine runs on conventional petrol, so drivers can fuel up at existing stations. (Production models are likely to have a different engine.)

4

A robust suspension will enhance on-road performance and enable takeoff and landing on relatively rough terrain.

fourth prototype, AeroMobil 3.0, to a grassy airfield in Nitra, Slovakia, unfolded its wings, and took off on the vehicle's maiden flight. It soared in a 20-km circle more than 800 feet off the ground and landed back at the same airfield. Since then, AeroMobil has completed more than 40 test flights. The company is now pursuing an airworthiness certification with the Slovak Federation of Ultra-Light Flying to permit expanded flight testing throughout the European Union. Meanwhile, further structural

and aerodynamic tests will help finalise the vehicle's design.

Because of stringent vehicle-safety regulations, the current prototype is intended for countries with more flexible road rules. The AeroMobil team hopes it will eventually be classified as a light-sport aircraft, which requires a pilot's license.

Future models may inspire their own class. "At the beginning, we'll need certification for both aeroplane and car," Klein says. "But this truly is a new category." **ERIC ADAMS**



5 Avionics from Garmin will include a two-axis autopilot to control pitch and roll. In case of emergency, the vehicle will have a ballistic parachute safety system like a light aircraft.

MEDICINE

Needle-Free Vaccination



Inventor:
Katarzyna "Kasia"
Sawicka

Company:
ImmunoMatrix LLC

Invention:
ImmunoMatrix

Development cost to date:
\$100,000–200,000

Maturity



Vaccines save lives, but most of them are delivered by needle. That's a problem for people without access to refrigerated solution, clean syringes, and safe ways to dispose of medical waste. Biomedical engineer Kasia Sawicka invented a painless alternative: a patch, called ImmunoMatrix, that can vaccinate patients without breaking the skin. "This technology can affect how vaccines are delivered, especially during pandemics," Sawicka says.

By design (or at least, by evolution), our skin doesn't absorb large molecules easily, which meant Sawick had to find another way to get vaccines across that barrier. As an undergraduate at Stony Brook University, she worked in a lab that stocked an extremely water-absorbent material called polyvinylpyrrolidone. She found that this polymer (used in hairspray during the era of beehive hairdos) could pull water out of the skin. When moisture returned, the outer layer of the skin swelled, allowing larger-than-usual molecules to enter.

Over several years, Sawicka perfected a process that involves combining the polymer with vaccine solution, forming it into nanofibres with large surface areas, and weaving those fibres into dense mats. In tests on rats and synthetic human skin, the patches delivered vaccine molecules

250 times larger than those the skin typically absorbs. No little pricks necessary.

ALEXANDRA OSSOLA

Special packaging lets the patches go without refrigeration for 10 weeks, far longer than a vaccine solution.



BRE'S ADVICE



TIP #1

Be an early adopter. Try buying a bitcoin. Set up a Raspberry Pi as an arcade machine. Doing things gets the juices flowing and gets you thinking in new ways.

COMMUNICATION

A Braille Printer Born From LEGO



The world's cheapest Braille printer got its start with a single piece of mail. Upon seeing a letter soliciting donations for the blind, Shubham Banerjee, then 12 years old, asked his parents how blind people read. They suggested he Google it. Banerjee's Internet search turned up Braille printers, all of which cost more than \$1,800. So he set out to make a cheaper alternative using his favourite toy—LEGO.

Banerjee finished building his first prototype, Braigo, in February 2014. But the device was limited to printing on narrow rolls of paper. "I still love LEGO, but I had to move on to something that would be released into the market," he says.



Inventor:
Shubham Banerjee

Company:
Braigo Labs Inc.

Invention:
Braigo

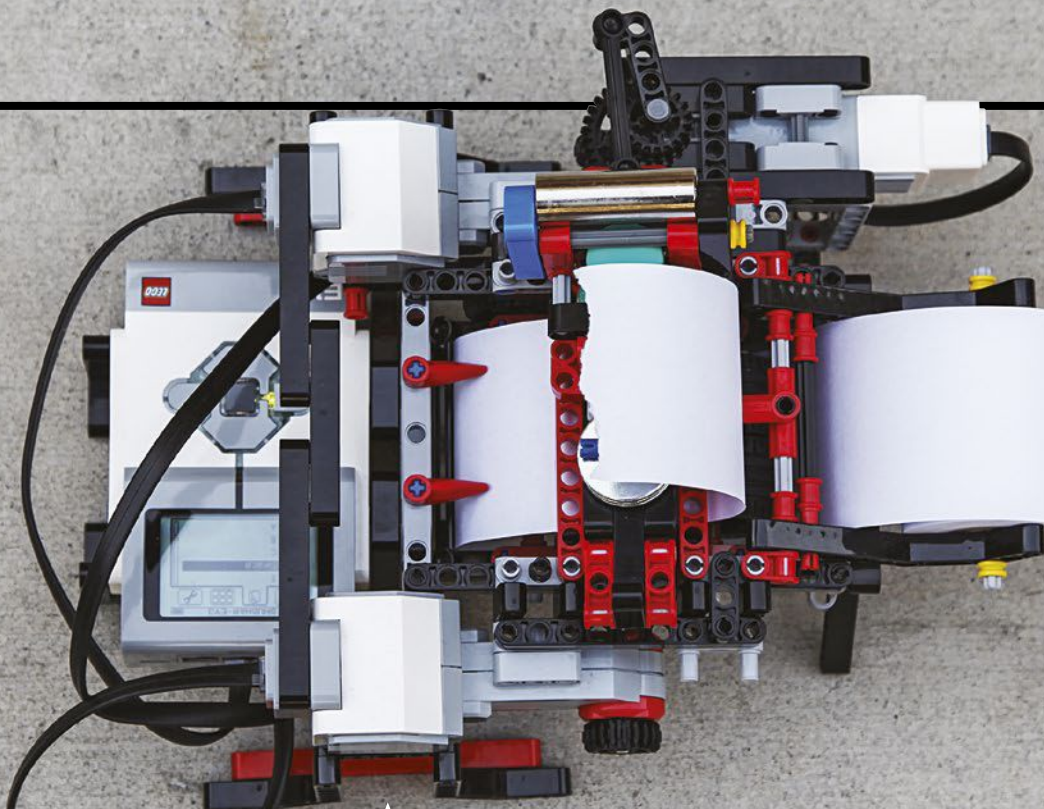
Development cost to date:
Undisclosed

Maturity:
◆◆◆

In 2014, Banerjee formed Braigo Labs with the help of his parents. Later that year, he released the prototype for Braigo 2.0 at the Intel Developer Forum, and Intel Capital offered him seed funding for further R&D. Along with a team of advisers, Banerjee, now 13, is currently refining the second iteration of his printer, which will be made of fabricated

printer parts powered by an Intel Edison chip.

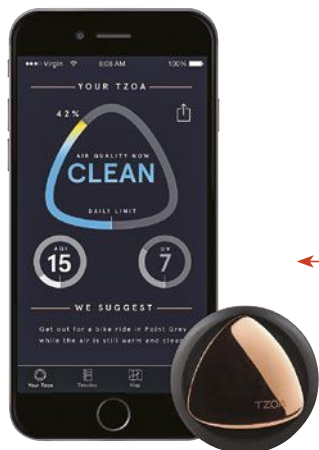
Like its predecessor, Braigo 2.0 is light and portable—but it's far more advanced. Using both Wi-Fi and Bluetooth, its chip will connect the printer to a webpage where users can type standard text. Braigo will automatically translate the words into Braille, converting a 160-page



The first version of Braigo, built with parts from LEGO's Mindstorms robotics kit, used a thumbtack to punch Braille dots into paper. Banerjee put the design and software for Braigo 1.0—which costs about \$355 to make—online for free.

WEARABLES

Personal Pollution Monitor



Journeyman electrician Kevin R. Hart and nurse Laura Moe are the type of people who attend Environmental Protection Agency events for fun. They're also the type who leave an

A fan directly beneath TZOA's triangular cover sucks in air. As pollutants cross a laser, they scatter light onto a sensor that counts them. TZOA then glows a colour corresponding to the air safety level. A smartphone app also displays that data, along with daily UV light exposure and crowdsourced pollution maps.



Inventors:
Kevin R. Hart and Laura Moe

Company:
TZOA Wearables

Invention:
TZOA

Development cost to date:
Undisclosed

Maturity:
◆◆◆◆◆

event, as they did in 2013, determined to help solve the planet's single largest environmental health risk: air pollution. Most cities rely on just a handful of expensive air monitors to detect hazardous pollution levels. Hart and Moe decided to build a wearable device that collects data everywhere a person goes.

After planning out how the sensor would work, the pair turned to the resources at MakerLabs, a community workspace in their native Vancouver, British Columbia, for further development. "We used basically everything in the building," says Hart. A group of physicists renting space on the top floor worked with them to build an accurate air pollution monitor smaller than anything on the market. Industrial designer Afshin

BRE'S ADVICE

TIP
#2

Seek out mature industries—ones that haven't been automated or touched by the Internet. Disrupt them by making things networked, better, and more affordable.

document in 35 seconds.

Once printers are ready, they will be sent to various institutes for the blind for testing and feedback. The final model, planned for release in late 2015, will sell for less than \$500, making it the first—and only—low-cost Braille printer.

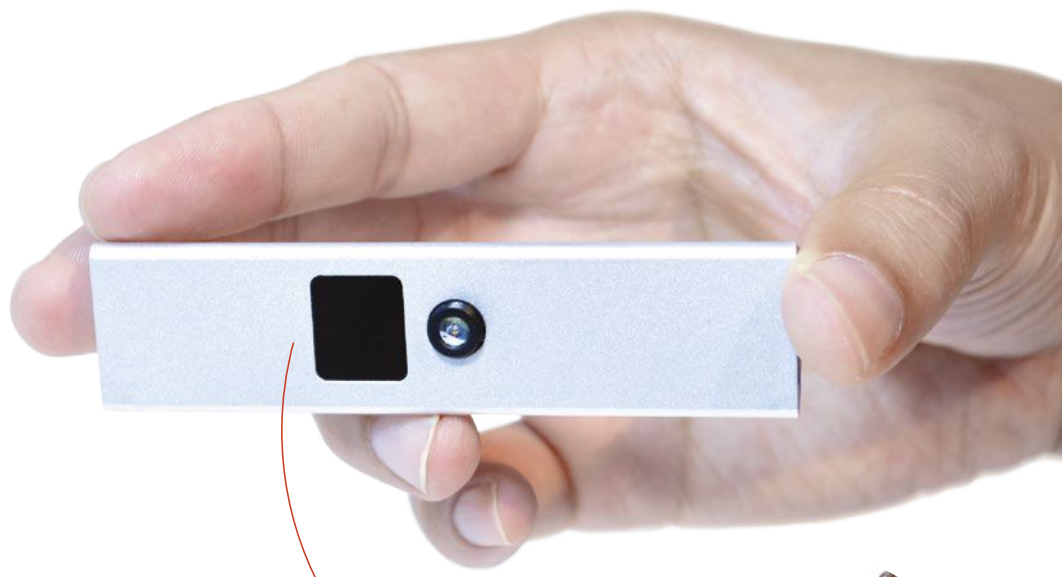
ALLIE WILKINSON

Mehin helped make the device beautiful. The size of an Oreo cookie, the sensor measures particulate matter, a key air pollution component, as well as ultraviolet light.

Hart and Moe plan to sell TZOA, as they named the monitor, for US\$99, in late 2015. Citizen-scientists want the sensors to pinpoint polluters, but Hart sees bigger potential for individuals who want to protect their health.

Using data from TZOA, parents can keep infants away from pockets of pollution, and athletes can plan workouts for the least-polluted routes and times of day.

MADELINE BODIN



Nimble Sense could let VR users grab and throw a digital object or even pluck the strings of a virtual guitar.



GAMING

Hands-On Virtual Reality



When peering through a virtual-reality headset, players can't see their hands—or use them to interact with their digital surroundings. To solve VR's interaction problem, software developers Robert Wang, Chris Twigg, Kenrick Kin, and Shangchen Han formed a start-up, courted investors, and got to work.

The four had spent years working with motion-tracking camera systems and developing algorithms that monitor and analyse skeletal structure. With their experience, it didn't take long to craft software that tracks joint angles and knuckle placement to create realistic virtual hands. But they couldn't find a camera sensitive enough to pick up such data. "We played with them all," Wang says. "There was no

depth-sensing camera good enough for VR hand tracking." Existing videogame motion trackers, such as Microsoft's Kinect, are designed to detect large objects, such as a bouncing 22-year-old two metres away, not subtle hand movements.

The team set out to design its own specialised camera, Nimble Sense, small enough to fit over an Oculus headset and with a field of view optimised for VR. It monitors users' hands, and software then digitally mimics every gesture. Facebook-owned Oculus VR was so convinced it bought the start-up, Nimble VR, last December. Now, the developers are working to make Nimble Sense even better. "There are still a lot of interesting problems left to be solved," Wang says. **MO MOZUCH**



Inventors:
Robert Wang,
Chris Twigg, Kenrick
Kin, and Shangchen
Han

Company:
Nimble VR

Invention:
Nimble Sense

**Development cost
to date:**
Undisclosed

Maturity:
◆◆◆◆◆

AUTOMOTIVE

A Self-Balancing Vehicle



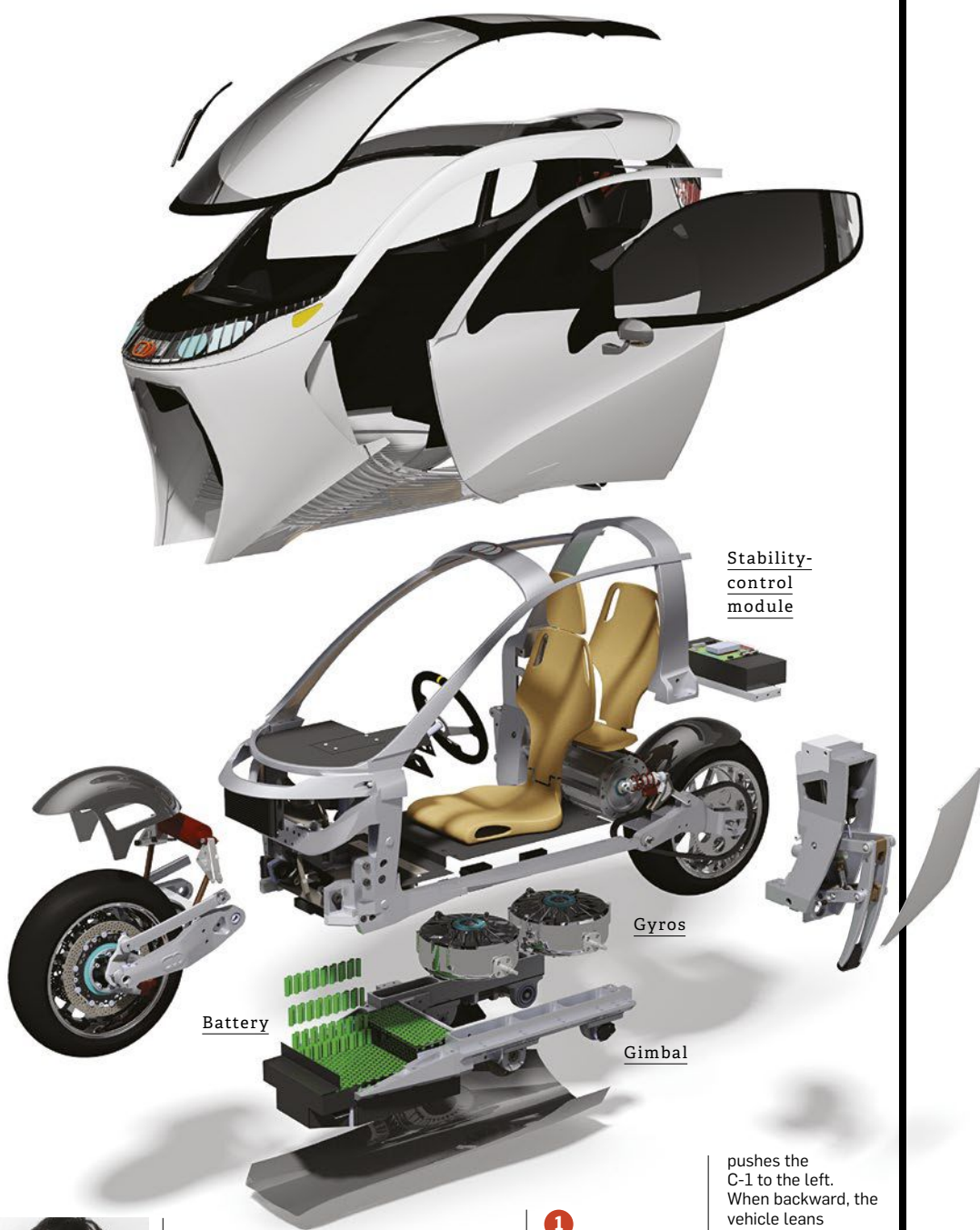
Daniel Kim thinks most commuters drive around in way too much car. For single-passenger trips, motorcycles are much more fuel-efficient—a critical feature in an era of climate change—but they are also more dangerous, expose riders to the elements, and require skill to keep upright. Kim's solution? Cut the car in half.

His all-electric C-1 prototype has two wheels, like a motorcycle, but a steel, aluminium, and composite outer body, like a car. It can even drive backward. If you sit inside the C-1 and sway from side to side, a gyroscopic control system keeps the vehicle upright. "When was the last time you balanced on a motorcycle at zero miles an hour?" Kim asks rhetorically. "Never."

A two-time college dropout, Kim hatched his idea in 2004, while running a business customising cars. That's when he narrowly missed being crushed under the 225-kilogram stripped-down chassis of a Land Rover (it nearly fell on him). He emerged with the conviction that no single person needs such a large vehicle. Kim went back to college and graduated from the Rhode Island School of Design. Then, concept in hand, he raised \$3.5 million in venture capital—enough to launch Lit Motors in 2010.

The allure of a self-stabilising two-wheeler has tempted automotive designers for at least a century. Earlier attempts, however, had fatal flaws—the gyros were too large, the mechanical control systems too crude. The C-1 instead employs computer-directed control-moment gyros, the same tools currently steering satellites in space.

Kim says the finished vehicle



Inventor:
Daniel Kim

Company:
Lit Motors

Invention:
C-1

Development cost to date:
\$3.5 million

Maturity:
◆◆◆◆◆

should go from zero to 100 km/h in six seconds or less, reach a top speed of 160 kilometres per hour, and enjoy a 300-km range. He hopes the product will hit the market within two years but admits that the challenge is substantial. "There is no real academic track for learning how to start your own car company," Kim says, "so I had to make it myself."

JAMES VLAHOS

1

Two gyros located beneath the seat whirl clockwise at 5,000 to 12,000 rotations per minute. Like any rapidly spinning disc, such as an airborne Frisbee, the rotors naturally stay level.

2

Single-axis gimbal assemblies, which hold the gyros, can tilt forward and backward. When tilted forward, the gyro generates a powerful torque that

pushes the C-1 to the left. When backward, the vehicle leans to the right.

3

The computerised stability-control module changes the tilt of the gimbals to keep the C-1 balanced. The vehicle remains level when driving straight or standing still and leans at an angle when making turns.

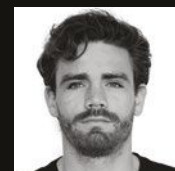
4

A 10.4 kilowatt-per-hour battery pack lasts 200 to 300 kilometres on a single charge.

1 The ceramic outer shell has a chemical makeup similar to that of coral, which encourages polyps to take root. Its textured surface gives smaller organisms places to hide from predators.

2 Concrete, reinforced by composite rebar, gives the reef a durable core. These materials can last at least 60 years underwater.

3 The open shape allows strong currents to move through the reef without knocking it over. The structure also traps eddies, which carry the nutrients that feed marine organisms.



Inventor:
Alex Goad
Company:
Reef Design Lab
Invention:
Modular Artificial Reef Structure
Development cost to date:
\$11,500
Maturity:
◆◆◆◆◆

ENVIRONMENT

An Artificial Reef for Any Seafloor



During a 2011 trip to Miami, Alex Goad went scuba diving and explored the artificial coral reefs off the Atlantic coast. Such reefs, he realised, are large, heavy, and expensive to fabricate and install. But they serve an important purpose. Natural coral reefs are some of the most biodiverse places on Earth, and they've begun to disappear, leaving thousands of species essentially homeless. Building

up artificial reefs where real ones have been lost is one stopgap solution.

So for his final project as an industrial-design student at Monash University in Melbourne, Goad created the Modular Artificial Reef Structure (MARS). Locking and clamping mechanisms on the arms of each MARS unit allow them to snap together easily, like LEGO. The modular structure makes MARS more

flexible than other artificial reefs. "A lot of existing products require a flat seafloor. But around the world, the ocean is not flat, especially where reef systems occur," Goad says. "With MARS, you can build over natural features, as much as you want."

After graduation, Goad teamed up with his supervisor David Lennon, the director of Sustainable Oceans International, to found Reef Design Lab and make MARS a real home for marine life. It took between 10 and 15 prototypes to find the ideal materials, surface texture, size, and weight for the units, which they tested in aquariums and in Port Phillip Bay. Goad and Lennon plan to release MARS this year for purchase by environmental organisations and coastal communities. "When local communities physically build the artificial reef, they gain a greater appreciation for natural reef systems," Goad says.

LINDSEY KRATOCHWILL

BRE'S ADVICE



TIP #3

Embrace the absurd. Everything we take for granted now was weird when it first came out. While building your automated pinball-machine cocktail-serving robot, you may just discover something truly innovative.

Invention Awards

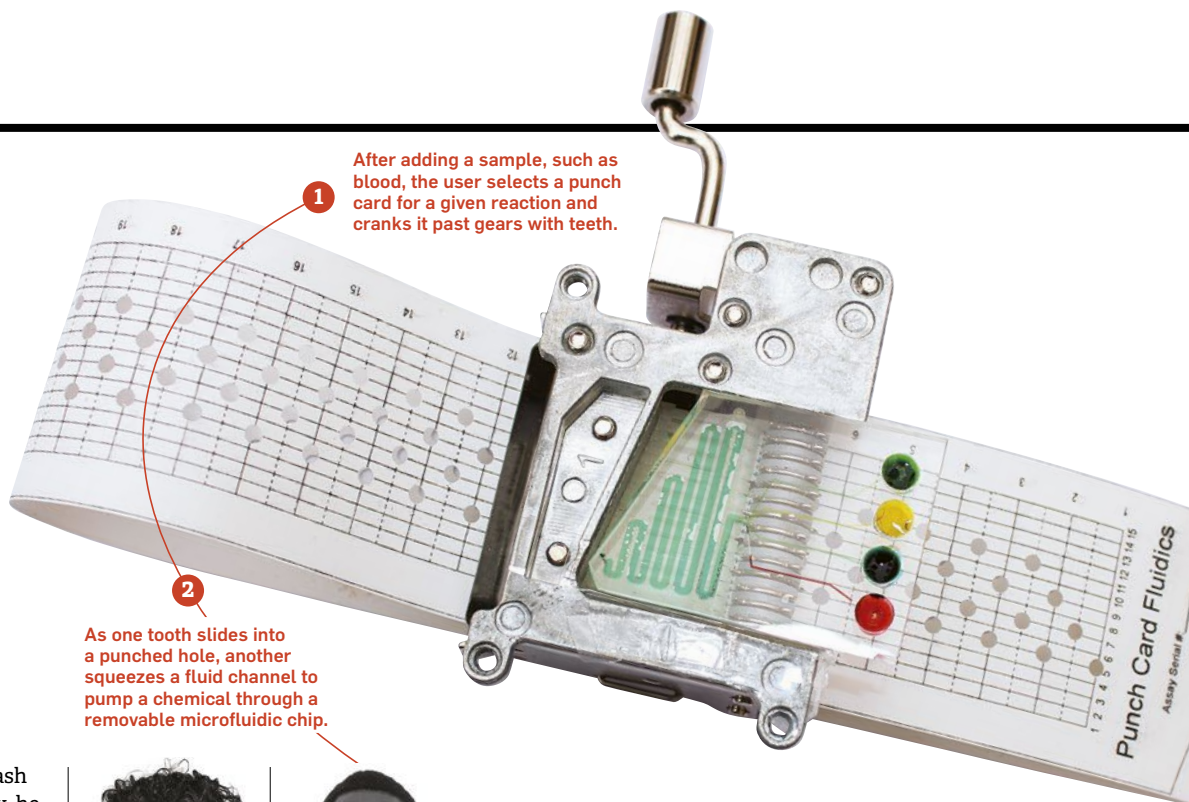
HEALTH

Medical Lab in a Music Box



One night in 2011, as Manu Prakash turned the handle on a music box, he realised the simple mechanism—a crank rotating gears—could also run a programmable chemistry set. Most “lab-on-a-chip” devices require computers, technicians, and expensive laboratories to pump precise amounts of liquid through a microfluidic chip. But a hand-cranked mechanism could eliminate all that; Prakash’s idea wouldn’t even need power. “What we’re doing here is steampunk chemistry,” he says.

Prakash, who heads a Stanford University research lab, recruited graduate student George Korir to help create a sophisticated scientific device that works like a music box.



1 After adding a sample, such as blood, the user selects a punch card for a given reaction and cranks it past gears with teeth.

2 As one tooth slides into a punched hole, another squeezes a fluid channel to pump a chemical through a removable microfluidic chip.

3 Punched holes can also trigger the release of a single droplet, for precise volume control.

4 Up to 15 different chemicals react with one another as they travel along channels etched on the chip.

**Inventors:**

Manu Prakash and George Korir

Affiliation:

Stanford University

Invention:

Punchcard Programmable Microfluidics

Development cost to date:

\$50,000

Maturity:

First, the duo had to figure out how paper punched with patterns of holes—each keyed to a different chemical reaction—could activate tiny mechanical pumps and valves to generate nanolitre droplets. Twenty-some prototypes later, they’re preparing their apple-sized invention, Punchcard Programmable Microfluidics, for mass production.

While conventional microfluidic pumps can cost \$1,500 each, Prakash says this device, which contains 15 pumps, will run a platury \$5.

Relatively simple to use, the instrument will enable anyone with a chip and a hole punch to perform a complex chemical reaction, such as diagnosing disease from a blood sample. Even lightly trained medical

ELECTRONICS

A Printer for Circuit Boards



While studying mechatronics at the University of Waterloo in Ontario, Canada, Alroy Almeida, Jesus Zozaya, and James Pickard were frustrated by the inefficiency of designing

One print head deposits a custom-formulated, highly conductive silver nanoparticle paste. Another extrudes insulating ink to form layers of circuitry without risking electrical shorts. Solder paste from a third print head can attach components, such as resistors or microcontrollers, to the board.

**Inventors:**

Katarina Ilic, Alroy Almeida, Jesus Zozaya, and James Pickard

Company:

Voltera

Invention:

V-One

Development cost to date:

\$200,000

Maturity:

circuit boards. “We’d spend a couple hundred dollars to get prototypes made at a factory, wait a few weeks, and they would come in wrong,” Almeida says. After they revamped the design, the agonising process would begin again, sometimes through multiple prototypes.

Meanwhile, they watched as 3D printers rapidly prototyped other kinds of products. An inkjet printer that deposited circuits would speed up electronics design—but

BRE'S ADVICE

TIP
#4

Invent things that make people's lives easier, safer, or more creative. Explore big problems—what could you invent to get me from New York City to London in 15 minutes? Explore small problems—what would it take to manufacture nano-scale ball bearings?

5

The user examines the results via embedded lenses that magnify images hundreds of times.

providers in rural areas and developing countries could identify, and thus control, fatal illnesses. "I grew up in Kenya and saw a lot of preventable suffering," Korir says, "so I'm passionate about getting the right tools to the people who stand between life and death." **ELBERT CHU**

conductive material was too thick to squeeze through existing print heads. So when the friends graduated in 2013, they teamed up with nanoscientist Katarina Ilic to build their own device. Two years of R&D later, the team is preparing to ship.

V-One's swappable print heads lay down conductive circuits on fibreglass boards. By using its solder function to attach components, users can even produce small batches of their devices. Almeida hopes the printer will usher in a new generation of engineers. "This can help people understand that electronics don't need to be difficult." **SHANNON PALUS**

**Inventors:**

Humberto Evans,
Mike Robbins,
Kyle Moss, and
Yuan Wei

Company:

CircuitLab Inc.

Invention:

Pantelligent

Development cost to date:
\$20,000+

Maturity:

GADGETS

A Frying Pan That Teaches You to Cook



Instead of eating at dining halls in college, Humberto Evans cooked his own meals. His best friend, Mike Robbins, on the other hand, could barely fry an egg. Robbins would forego the lure of takeout only when Evans gave him step-by-step cooking instructions. The two realized that others probably needed some culinary hand-holding as well. With help from two other MIT engineering alumni, Kyle Moss and Yuan Wei, they created the world's first smart frying pan: Pantelligent.

The pan measures its temperature with heat sensors and transmits the data via Bluetooth technology in its handle. A smartphone app uses

this information to decide when it's time for a recipe's next step and then tells the user. "To cook amazing food the way chefs do, you have to build intuition for how long to cook something at the right temperature," Evans says. "We take that knowledge and package it into our app."

Users can choose a preprogrammed recipe, such as chicken adobo or fried eggs, or select freestyle mode to get temperature readings but not instructions. If a person likes the meal made in this mode, he or she can record and share the recipe. With a tool that de-stresses the kitchen experience, the Pantelligent team hopes more people will skip unhealthy processed meals in favor of home-cooked ones. **JUNNIE KWON**



OUR
PLACE
IN —————>



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HOW AUSTRALIA PUNCHES
ABOVE ITS WEIGHT WHEN
IT COMES TO THE GLOBAL
SPACE INDUSTRY, AND WHY
NASA RELIES ON US FOR SOME
OF ITS HIGHEST PROFILE
INTERPLANETARY MISSIONS.

STORY BY **Peter Zalunzy**

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Oz Space Program

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OP-TIER ASTRONOMY

and space-related research is typically associated with NASA, so it tends to come as a surprise to some people when they learn that,

not only does Australia have a wide-spread space program, our scientists, astrophysicists, engineers and other academics are among the leaders in their respective fields. Sure, the Parkes Radio Telescope may be the most well known installation outside the scientific community, but Antipodean astronomy extends across many observatories and research centres across the country, investigating everything from environmental changes on Earth, to the history of the universe immediately after the Big Bang.

While it's impossible to sum up all of the ongoing research and collaboration in anything short of a book, but there are some particularly prominent projects currently underway around Australia that should interest anyone with even a casual interest in the night sky.



MAPPING THE UNIVERSE: THE ASKAP SURVEY

Way out in the Murchison region of Western Australia, 36 CSIRO radio telescopes, each 12 metres in diameter, are spread out across 4000 square metres of desert in an array known as the Australian Square Kilometre Array Pathfinder or ASKAP for short.

It will eventually connect with a similar array currently under construction in South Africa, completing an observation network called the Square Kilometre Array (SKA) that will have a sensitivity 50 times greater than other radio instruments.

The project will be directed from SKA HQ, which operates out of Jodrell Bank Observatory in Cheshire, England.

While phase one, the South African arm

HONEYSUCKLE

Out the back of Canberra, this tracking station famously brought the world images from Apollo 11. The entire site was dismantled in 1981.

of SKA, isn't due to start construction until 2018, the Australian branch has undertaken a handful of observations to showcase its capability as an independent facility. At the same time however, ASKAP is part of the Australian Telescope National Facility (ATNF) and therefore will be working in conjunction other ATNF facilities such as the Parkes Radio Telescope.

At the moment the completed portion of ASKAP is undertaking surveys of the night sky, but eventually the total combined power of SKA will allow observation right back to the period between the Big Bang and the formation of the first galaxies.

As well as being able to answer crucial questions about the formation of the universe, these seldom explored corners of space can open the doors to new areas of physics research and even bring astrophysicist closer to understanding dark matter and energy.

So just how powerful is it? In January this year ASKAP created an image of the Tucana constellation three times larger than any other produced before, in just 12 hours, which, as Dr. Lisa Harvey-Smith, Project Scientist for

ASKAP explains, is no small feat.

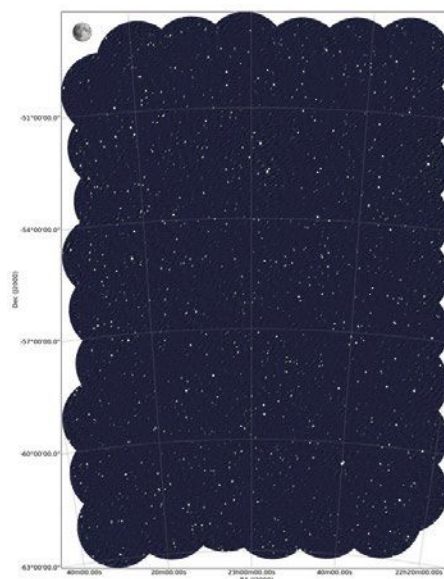
"Normally it takes months can take months or even years with a traditional radio telescope because we have to point the telescope at one place, sit there for 12 hours and collect the signal, then move it to the next point and sit for 12 hours," Harvey-Smith continues. "What we have now is currently 30 times the field of view of a regular receiver, so we can study over 100 square degrees of the night sky for example, we can see about four or five thousand galaxies in just one night."

This wide field of view is possible due to an Australian invention called the Phased Array Feed (PAF), which sits atop each ASKAP antenna, allowing each one to measure radio signals 30 times in different locations. PAF can also produce highly detailed images and transmit large amounts of data at high speeds into the accompanying telescope which, in the case of ASKAP, can reach up to 1.9 terabytes a second.

"When we look at the universe now, it's kind of the way any of us may go outside and look at hills in the distance, you know there are trees on those hills but you couldn't tell

BIGGER ANTENNA, BIGGER PICTURE

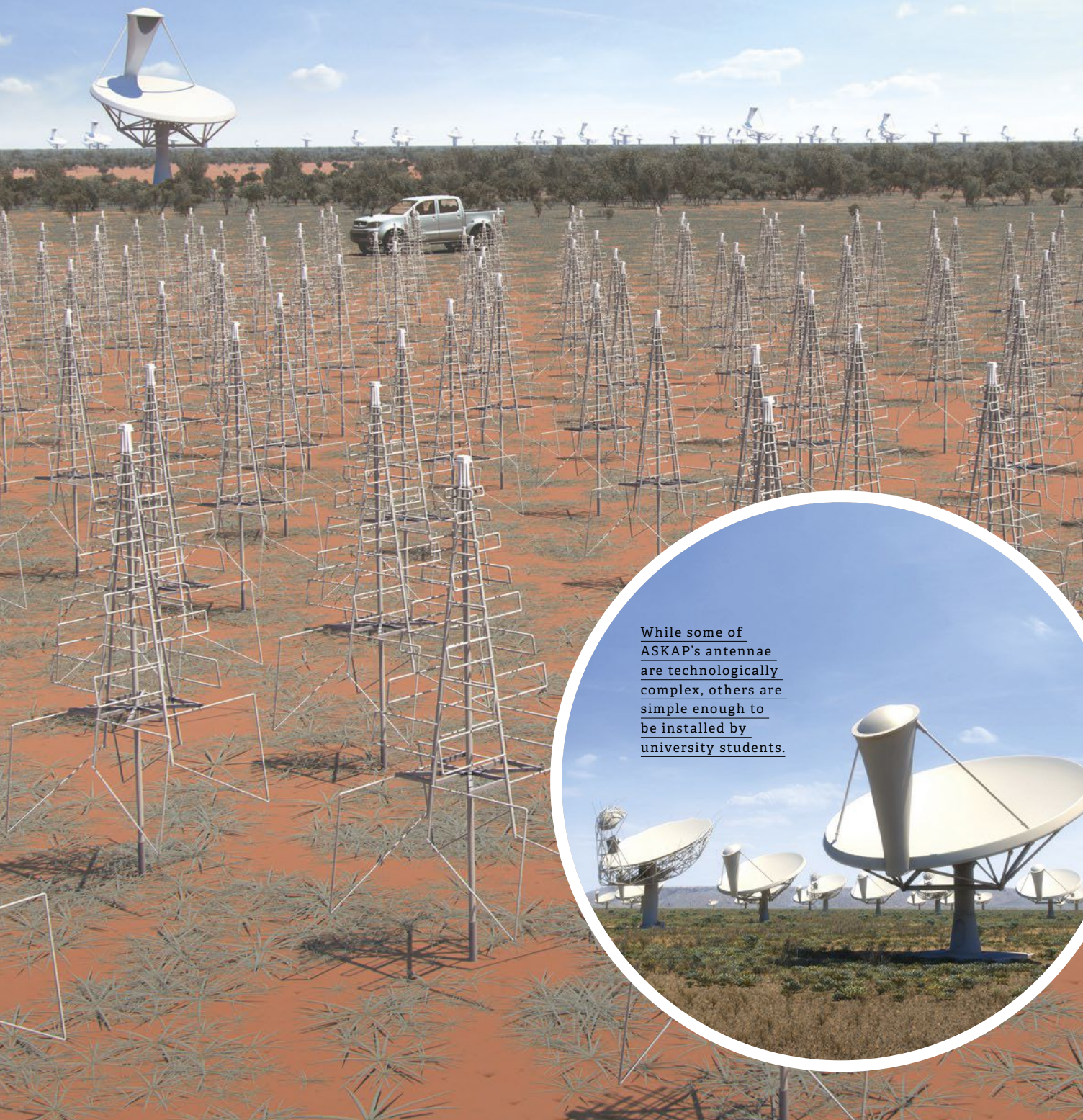
An optical telescope must focus light onto a single mirror (or a close cluster of mirrors) to create an image. A radio telescope is rather more flexible. It's possible to position antennae many metres or even kilometres apart, creating a virtual telescope of extreme sensitivity. Indeed, the theoretical maximum size of a radio telescope is an array covering nearly an entire hemisphere of the Earth. Of course, radio telescopes do not produce an "image" that human eyes would understand. Instead, the signal received can be interpreted in a vast number of ways.



IN THE MIDDLE OF NOWHERE?



ASKAP sits in a sparsely populated desert, 350km inland from the nearest major city in Western Australia. But this is the ideal location due to limited human activity, extremely low radio interference and unique ionospheric stability and benign tropospheric conditions, both of which improve the equipment's observational capabilities. In July 2011, special measures were put in place to ensure the area remains radio-quiet, and the CSIRO also released a series of instructions for visitors and surrounding farmland, regarding the use of radios, walkie-talkies and mobile/satellite phones among other devices.



While some of
ASKAP's antennae
are technologically
complex, others are
simple enough to
be installed by
university students.

Oz Space Program

us how many leaves are on the tree," explains Glen Nagle, education and outreach manager at the CSIRO. "So imagine if you had an instrument that could determine the gender of one bug crawling on one leaf on one of those trees in the distance, that's kind of what the SKA with these PAFs will be able to do with galaxies in the far reaches of the universe." The PAF has also made transient science - the monitoring of moving objects in the night sky - considerably easier as well.

Eventually, ASKAP and SKA will monitor vast hydrogen clouds and powerful magnetic fields to answer the myriad questions around the formation of galaxies.

Astrophysicists believe that stars are formed by a gravitational agglomeration of hydrogen, but so far they haven't found enough hydrogen in the universe to support that theory. Until now. "We found a huge reservoir of hydrogen in a very distance galaxy and that's interesting not just because it's a blob of gas," says Harvey-Smith, "but because we want to understand how the stars form and the star formation history of the universe as well. We [also] think magnetic fields spill out into interstellar and intergalactic space and that may be key in building stars and shaping things like planetary nebulae and supernova remnants."



BACK TO THE BEGINNING

Between the Big Bang and the initial evolution of universe, is a gap of around 150 to 800 million years known as the Dark Ages or Dark Period. Towards the end, the earliest stars emerged from the primordial hydrogen, re-ionised and became the first galaxies. So what happened in the 800 million year interim? No one really knows, which is why astrophysicists like Simon Johnston, head of Astrophysics at the CSIRO Department of Astronomy and Space Science, will be using the SKA to hopefully find out.

"We don't really understand how the universe came from something that was very smooth, as seen in the cosmic microwave background, into producing lumpy things like galaxies," he explains. "There's an idea that

Built after the fire at Mt Stromlo,
the new Advanced Instrumentation
Technology Centre means we can
now build satellites



Tidbinbilla: the place where you talk to Voyager II in the morning, and upload new mission parameters to the Opportunity rover after lunch.

which could also unlock information about the evolution of the universe, particularly with regards to the formation of early black holes.

Scientists search for these waves by observing pulsars, small stars which typically spin up to 500 times per second and can be used as very accurate universal clocks.

A perturbation in these clocks usually means that a gravitational wave has passed by, but while astrophysicists have observed what they believe are the effects of these waves, no one has managed to directly detect a gravity wave and so they still remain in the realm of the theoretical.

"So where do we expect to see these things from?" Johnston asks. "From very massive black holes a billion times the mass of the sun, in orbit about each other in the early universe, and we want to understand how these massive black holes got there in the first place."

Most of the research takes place at Parkes, which can accurately measure pulsar rotation rates down to 15 decimal places.

But we're not the only country looking for gravitational waves. The LIGO experiment in the US, which uses a large laser interferometer to directly detect these waves, is also hot on the trail.

"LIGO itself has been off the air for a couple of years while they upgrade the detectors," explains Johnston. "They're about to switch on again and they're expecting to find something by the end of this year, so we're in a race with them to see if we can see something by then."

Even so, Johnston believes that the odds of spotting a gravitational wave aren't quite that good. "I would say our chances are probably worse than fifty-fifty but we're going to give it a crack," he says with a laugh. "We've been in this game since about 2005 so it's been about a decade already, and we've solved a lot of the problems, we're getting better and better but we're not quite there yet."



TAKING OUT THE TRASH

Despite much of the site being lost to the devastating 2003 bushfires, Mt. Stromolo in Canberra continues to be an important space research facility that works in conjunction with the Research School of Astronomy and Astrophysics (RSAA) at the Australian National University.

Scientists, engineers and astrophysicists, collaborate on multiple research projects

SPACE LTD

For more information on Australia's space industry in general, visit the Space Industry Association of Australia at www.spaceindustry.com.au

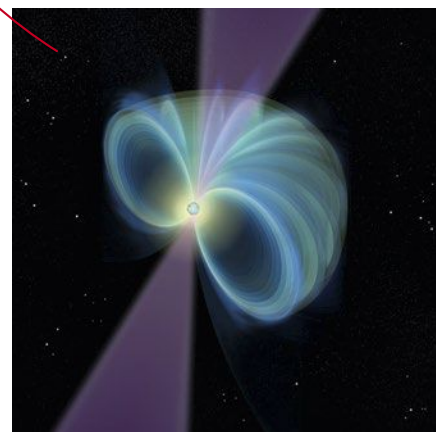
including (but certainly not limited to) optics design and environmental testing.

Lately, ANU teams have been constructing various instruments for the Giant Magellan telescope, a super-giant Earth based telescope which is currently under construction in Chili and due to be completed in 2020. As a broad indication of its capabilities, Magellan will have a resolving power ten times greater than the Hubble telescope. The final build will use information and components from 11 astronomy intuitions across the world.

Researchers have also teamed up with the Cooperative Research Centre for Space Environment Management at Mt Stromolo to track and eventually destroy the 20,000 pieces of debris (larger than 10 centimetres) currently orbiting earth.

This is problematic, because man-made satellites and the International Space Station area at risk of colliding with these large chunks, which could cause serious damage. The number of small pieces between one and ten centimetres is believed to be as 500,000, but this is an estimate because tiny debris is much harder to track.

"What we need to do is to be able to give that warning with such a high level of con-



These rapidly-rotating objects are fascinating to cosmologists, who use them for everything from super-accurate timekeeping to developing a sort of galactic GPS.



Many of these observations cannot begin until SKA comes online, since the wavelengths being studied are often in excess of a metre, which is too long for ASKAP to detect on its own.



DIGGING DEEP-ER INTO ASTROPHYSICS

Outside ASKAP and SKA, local and international astrophysicists continue to use ATNF telescopes to search for gravitational waves,

Oz Space Program

fidence that we can say we know that this piece of debris, we're tracking it accurately, we can predict where it's going to be and it's going to hit you, if you move you'll avoid it," explains Naomi Mathers, Industry Liaison Engineer at ANU and Mt Stromolo.

Moving satellites consumes a lot of fuel, which shortens their life, and at a very high cost. This is why scientists and the satellite operators would prefer to destroy space junk altogether.

"If we can perturb that small piece of debris, that may be the better option," says Mathers. (By perturb, she means shoot down.) "Ultimately you want to be able to move it enough so that you start pushing it down into a lower orbit, or change its orbit so it's caught by the atmosphere and is permanently burnt up."

So how does ANU plan to tackle this gargantuan task? With a giant space laser of course. At the moment, the North American Defence Command (NORAD) monitors a lot of the debris using radar, but this lacks the accuracy of laser tracking.

Electro Optic Systems (EOS) and RSAA responded to this by developing the Adaptive Optics Demonstrator, similar to the laser



system at the Gemini Observatory.

It has the ability to track large debris with much greater accuracy, and also spot considerably smaller pieces outside the detection limits of radar.

But there's more to developing this system than simply creating the technology.

Australian manufacturing:
fewer old-fashioned cars no-
one wants to buy, and more
state-of-the-art space lasers.

"There are a lot of legalities involved too," Mathers says. "You have to be able to identify and locate [junk] accurately and you need to be able to control it because the last thing you want to do is lose a bit and have it hit something. And one person's cleanup system is another person's space weapon, so you need to be working with the international political and legal environment as well as the technical environment."

A WORLD OF POSSIBILITIES

The Phased Array Feed is proving to be so useful, that the CSIRO is considering installing it on other radio telescopes such as Parkes. Outside astronomy, the PAF also has potential applications in medical imaging, body scanning and even reconstructing grainy CCTV footage for crime prevention.



ONGOING INTERNATIONAL COLLABORATION

Australian scientists and astrophysicists continue to work with major space agencies from all over the world including JAXA in Japan and NASA in the United States. The Canberra Deep Space Communication Complex (often just referred to as Tidbinbilla), which is operated by NASA's Jet Propulsion Laboratory (JPL) in California, regularly tracks the progress of, and receives data from, numerous NASA spacecraft.

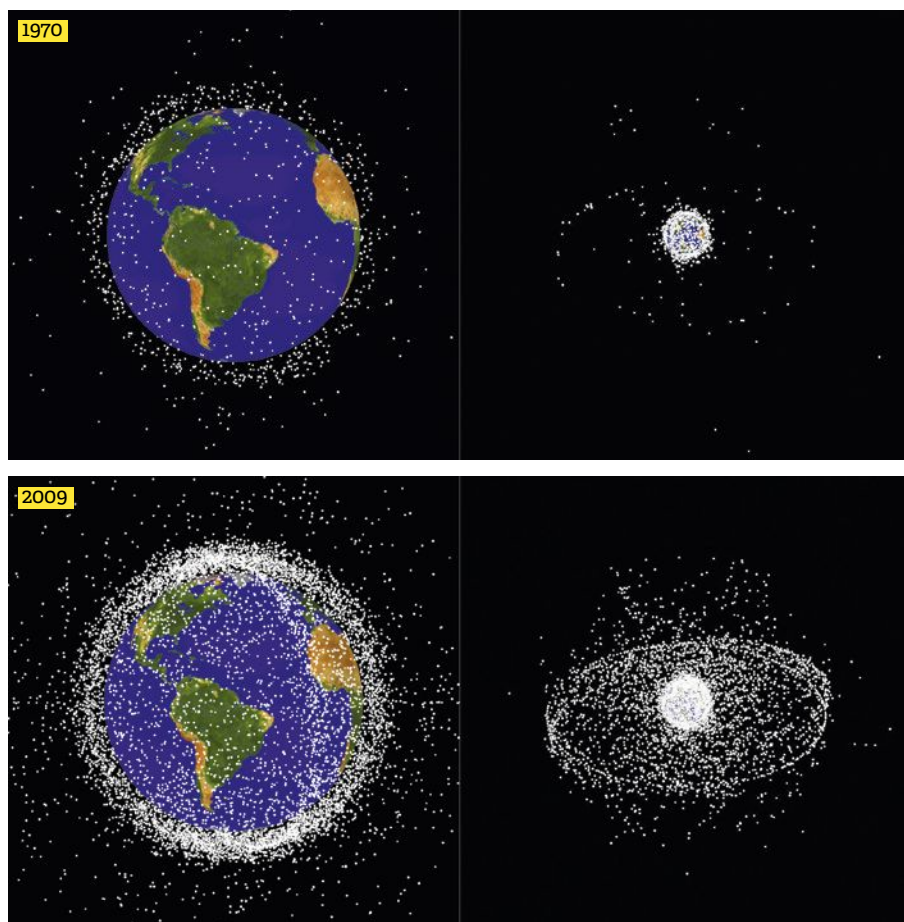
It's a very important facility, so much so that NASA has committed to two building

CLEAN UP YOUR ROOM!

As we approach 70 years in space, humans are starting to realise the scope of our space junk problem. Thousands of objects, from obsolete satellites to dropped spanners, now orbit the Earth. Each could potentially damage or even destroy the next multi-billion dollar space mission we launch. Many solutions have been proposed, but at Mt Stromlo, Australia is developing a powerful laser system to either "push" the junk into a less stable orbit (where it will fall back to Earth and burn up) or even "ablate" it - that means "blow it up with an enormous laser!".



Even tiny objects like this ball-bearing can be devastating at orbital speeds. Boom!



34 metre antennas to Tidbinbilla, the first of which was recently completed at a total cost of \$55 million. The second is due to enter operation towards the end of 2016. A third antenna is also being discussed and, if approved, will be completed around 2020.

One such collaboration reached an exciting point in early March 2015, when the Dawn Spacecraft entered orbit around the dwarf planet Ceres, some 4.9 billion

kilometres from Earth.

It's the first time a human craft has entered orbit around a dwarf planet, and Tidbinbilla has helped received important data on behalf of JPL.

"We're starting to get pictures from that object right now and seeing a brand new world for the very first time," explains Nagle. "It's smaller than our moon but seems to have diverse terrain, it could have outgassing of

ONE SUCH COLLABORATION REACHED AN EXCITING POINT IN EARLY MARCH 2015, WHEN THE DAWN SPACECRAFT ENTERED ORBIT AROUND THE DWARF PLANET CERES

water vapour from below the surface."

Similarly, Tidbinbilla will receive data from the New Horizons probe when it arrives at Pluto in July - at 9:40pm on the 14th to be precise. Due to its small-size (about the same as a piano), New Horizons does not have the necessary fuel to slow down, which leaves scientists with little more than a day to observe Pluto close up. Here, Tidbinbilla will help JPL to ensure that the trajectory is optimal - not a collision course, but close enough to ensure that the necessary data is recorded.

"At the moment the New Horizons probe is on approach, under 200 million kilometres from the planet," Nagle continues. "We will study it for the few months that we go in as we're doing now and afterwards when we go past, but we'll learn pretty much everything we'll need to know about Pluto in that close encounter."



THE TIP OF THE ICEBERG

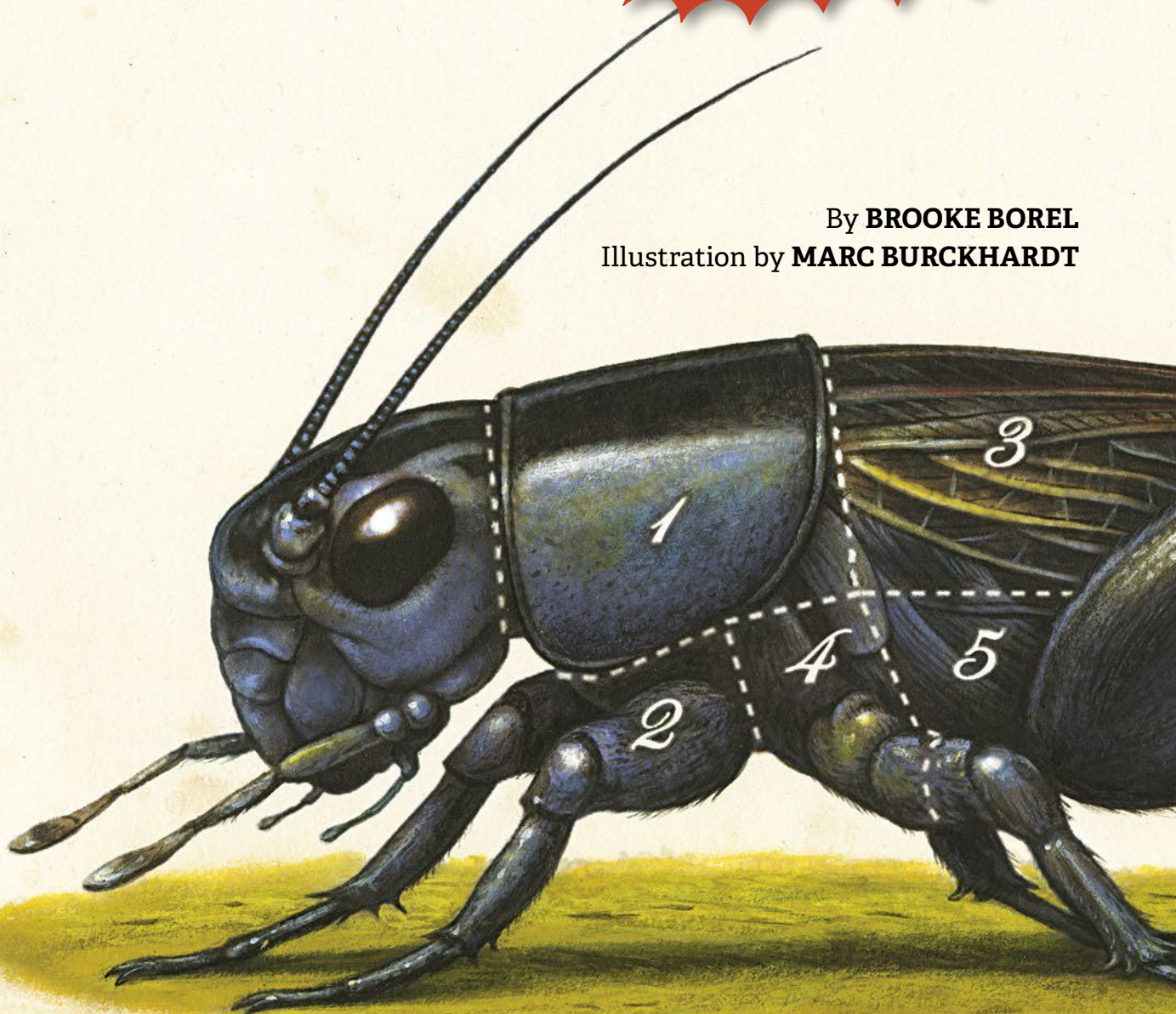
While these are some of the more prominent activities in the Australian space industry, they represent a small part of the extensive research that's currently underway. For example, local scientists often look straight back down towards Earth, to assess environmental changes which can benefit the agriculture sector. This is just one example, but all Earth observation research alone brings an estimated \$3.3 billion into national GDP at a total government expense of just over \$1 billion. But regardless of the field, the Australian space industry continues to make a significant contribution to astronomy research and development around the world.

THE RISE of the

EDIBLE!

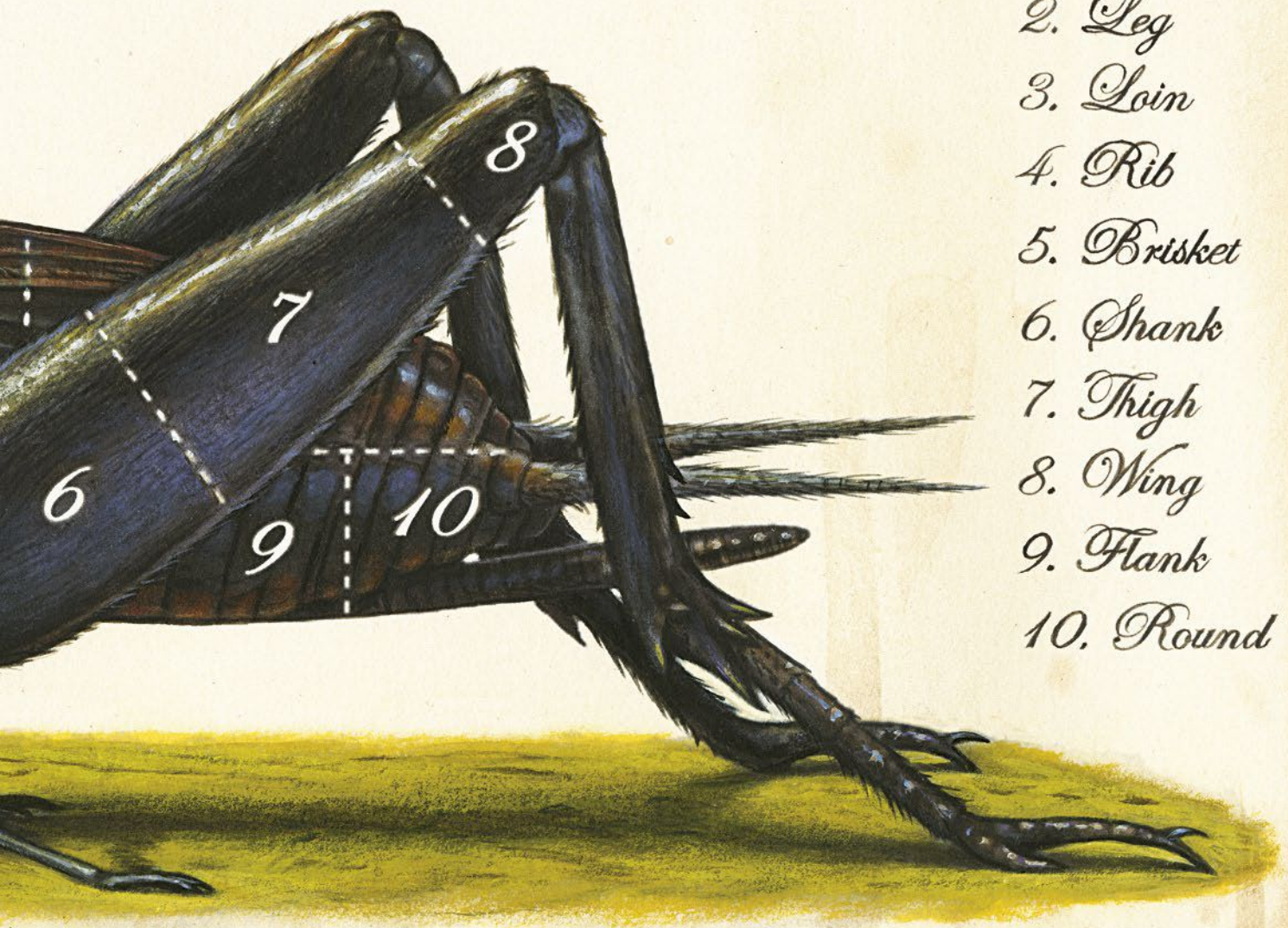
By **BROOKE BOREL**

Illustration by **MARC BURCKHARDT**



INCREDIBLE, INSECT

START-UPS ARE MARKETING AN UNLIKELY NEW PROTEIN. IT'S NUTRIENT-RICH, ALL NATURAL, AND SIX-LEGGED.



1. Chuck
2. Leg
3. Loin
4. Rib
5. Brisket
6. Shank
7. Thigh
8. Wing
9. Flank
10. Round



DURING THE LAST WEEKS of winter, in an airy kitchen at the School of Visual Arts in New York City, two design students set about making cocktail bitters. A long wooden table holds mason jars and gleaming bottles of bourbon, vodka, and neutral grain spirits. The fragrance of ingredients that will macerate over the next few weeks, until they surrender their flavour to the alcohol, hangs in the air. There are white bowls of toasted coconut and raw cacao, as well as a jar of cinnamon sticks. Then, there are the crickets.

Lucy Knops rolls up the sleeves of her loose black shirt and carefully pours each ingredient into a small, clear measuring cup sitting on a digital kitchen scale. Her classmate Julia Plevin records the weights in a spreadsheet. When she gets to the crickets, Knops leans closer and peers into the cup. “That’s so crazy,” she says, “there are so many legs!” I follow her gaze; dozens of wirey amputated appendages cling to the sides like the static trimmings from a haircut. Knops dumps the whole thing into an empty jar.

I am witnessing a test batch of Critter Bitters, which the pair first created for a school project in 2013. The challenge: make a product in response to a report by the Food and Agriculture Organisation of the United Nations (FAO) titled “Edible Insects: Future Prospects for Food and Feed Security.” The report noted that the global population, now at more than 7 billion, may grow to 9 billion by 2050. Already, nearly a billion people regularly go hungry. Insects—a source of protein that requires a fraction of the land, water, and feed as livestock—could help alleviate the looming crisis. “The case needs to be made to consumers that eating insects is not only good for their health, it is good for the planet,” the authors wrote. Knops and Plevin figured that while cricket-based bitters might not solve the food problem, the product could help overcome a psychological one. “People are more open to trying new things when there are cocktails involved,” Plevin says.

Most of the world has been comfortable with entomophagy, or the practice of eating insects, for millennia. But it is only in the past few years that it has gained momentum in Western countries, particularly with respect to crickets. More than 30 start-ups specialising in crickets have launched in North America since 2012. A few

raise the insects; the rest either sell cricket meal—milled to a fine powder that resembles nut flour—or products made from it, including cricket granola bars, cricket chips, cricket crackers, cricket chocolates, and cricket cookies. There are fledgling lines of dog treats too, and one company is working to mash crickets into a paste, the entomophagist’s answer to peanut butter. Late last year, the restaurant consultants Baum and Whiteman forecast that insect protein powder would be among the hottest food and drink trends of 2015, along with oysters, unusual root vegetables, and whiskey.

Critter Bitters abstracts the crickets further, filtering out the evidence rather than grinding it up. In fact, Knops and Plevin suspect that their pure cricket bitters—one of several flavours they plan to offer—may have fewer insect parts than are allowed in food by the US Food and Drug Administration (FDA); cinnamon sticks, for example, may legally contain up to five per cent insects by weight.

As I watch Knops pour alcohol into the jar of crickets, their bodies bobbing in a rising tide of bourbon, I squint into an older container of bitters—a batch from 2013, the students’ first. It’s now nearly gone. Knops and Plevin never suspected the bitters might become a commercial product, but after they presented their final project to the school, they started getting media attention, including from *Epicurious.com* and *Food & Wine’s* website. “The urge to do something to save a dying planet coincides with a very adventurous time in eating,” says Plevin.

...

North America’s cricket-food industry didn’t spring from a spontaneous, collective epiphany about shifting food tastes. Rather, it can be traced to two catalysts. One was the 2013 FAO report that sparked the birth of Critter Bitters. The other was a 2010 TED talk by Dutch ecological entomologist Marcel Dicke that has been viewed online 1.2 million times. Clicking

BAUM AND WHITEMAN FORECAST THAT INSECT PROTEIN WOULD BE AMONG THE HOTTEST TRENDS OF 2015, ALONG WITH OYSTERS AND WHISKEY.

through PowerPoint slides in an insect-adorned T-shirt, Dicke lays out the case for entomophagy. A burgeoning population will not only add more mouths to feed, he points out, but will require more protein; as people grow richer, they want to eat more meat. Then, there's the economic argument. "If you take 10 kilograms of feed, you can get one kilogram of beef," Dicke says, "but you can get nine kilograms of locust meat. If you were an entrepreneur, what would you do?"

In the US, both events rippled through a food culture that is increasingly self-aware, if not always scientific—one populated by gluten-free trendsetters, protein-heavy paleo dieters, and eco-conscious locavores—and through a start-up culture filled with young idealists. "This generation has greater access to knowledge than just 30 to 40 years ago," says David Gracer, a purveyor of exotic arthropods at SmallStock Food Strategies. "And when there are TED talks and FAO reports, they inspire a lot of people."

Thanks to crowdfunding sites like Kickstarter and Indiegogo, aspiring start-ups can now connect directly to an audience especially receptive to their message. Critter Bitters plans

to launch its first Kickstarter campaign this spring, in part to gauge the potential of its customer base. Terry Romero, Kickstarter's food outreach lead, has seen an uptick in insect-food projects. "Instead of the classic investor putting in a giant chunk of money, we are helping companies forge relationships with people who are emotionally invested in what they do," she says. "These will often be loyal fans for years to come."

Crowdfunding has also shown investors that there's a market to be tapped. Patrick Crowley launched Chapul, the first cricket protein bar in the US, with a \$16,065 Kickstarter campaign in 2012. Last year, Crowley was on the reality show *Shark Tank*, where small businesses pitch

to a panel of investors. By the end of the show, Crowley had convinced Mark Cuban, owner of the Dallas Mavericks pro basketball team, to invest \$50,000 for 15 per cent equity. And by the end of the year, Chapul had earned nearly \$400,000 from sales both online and in health food stores, food co-ops, and at Central Market, a gourmet chain. This year it will launch in select Whole Foods. "This was really a passion project to spread an idea," Crowley says. "I thought we were probably five to 10 years too early when we launched it; it's happening a lot faster than I had envisioned."

Another success was SixFoods, the creator of Chirps cricket chips, which raised \$70,599 on Kickstarter last year. Now, it's distributing

THE *m* GROCERY AISLE

Dozens of cricket-food start-ups have launched in the past few years—and nearly all disguise the insects in familiar products.



Exo protein bar
Varieties: cacao nut, blueberry vanilla, apple cinnamon, peanut butter and jelly; \$4



Bitty cookies
Varieties: orange ginger, chocolate cardamom, chocolate chip; \$13



Crickers crackers
Varieties: rosemary garlic, classic sea salt; \$8



Hopper Crunch granola
Varieties: toasted coconut, cranberry & almond, cacao & cayenne; \$12



Crittter Bitters
Varieties: pure cricket, vanilla, cacao, toasted almond; price N/A



Next Millennium Farms flour
Varieties: regular, organic gluten-free, organic; starting at \$18

Edible Insects

to co-ops in Boston and Seattle and is in talks with big-box stores. A cricket protein bar called Exo attracted \$54,911 on Kickstarter in 2013; the start-up has since sold several hundred thousand bars, raised an additional \$1.2 million, and may appear in JetBlue snack packs later this year. And Next Millennium Farms, which sells flour made from crickets it grows outside Toronto, raised \$1 million from private investors. "Some of the largest food production companies in the world are in talks with us—flavouring companies that sell to PepsiCo, Unilever, McDonald's," says co-founder Jarrod Goldin. "Food producers have had to pay attention to what is going on."

Many in the new cricket industry also hope

to ride a wave of other trends. Goldin, for example, sells organic and gluten-free cricket flour and will soon add a paleo line of crickets that are fed a grain-free meal. But regardless of the sales pitch, packing crickets into the familiar shapes of cookies and snack bars doesn't necessarily ease demand for more resource-intensive forms of protein (particularly with regard to products that may contain negligible amounts of cricket). The best scenario for entomophagy advocates concerned about global food security is getting people to eat the insects as they are.

"When we started ordering crickets to our dorm, we realised America isn't ready for that," says Laura D'Asaro, who co-founded

Six Foods shortly after graduating from Harvard. "We see our chips and cookies as a first step. It's useful just to have crickets on the ingredients list and have people eating them. But we want to slowly introduce other products, with the ultimate goal of going to a restaurant where you can get a chicken burger, veggie burger, or ento burger."

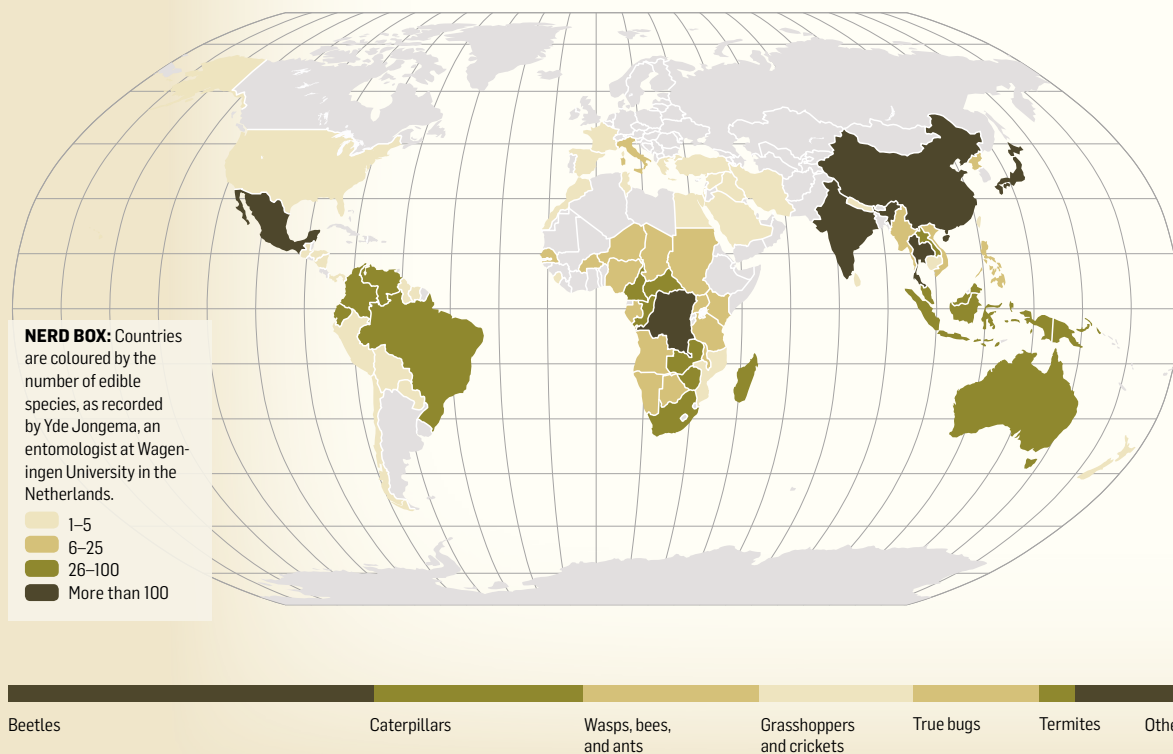
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The culinary possibilities of ento food rest on a steady supply of the main ingredient, which is another reason crickets have taken off. North America already has an industrial cricket infrastructure; the

THE GLOBAL MENU

The Thai love fried locusts. South Africans munch on caterpillars. At least 2 billion people worldwide regularly eat insects, according to the Food and Agriculture Organisation of the United Nations. Nutritionally, they are hard to

beat: Insects are high in protein, vitamins, minerals, fibre, and "good" fats. More than 2,000 species have reportedly been used as food—and with a million insect species and counting, more are sure to be found.



House Crickets
Asia, Americas
kJ* 1920
Protein 67 g



Palm Weevil
Africa, Asia, Americas
Larval palm weevils are by far the most popular beetle eaten in the tropics.
kJ 2000
Protein 36 g



Ahuahutle
Americas
The eggs of back-swimming bugs have been eaten in Mexico for centuries.
kJ 1380
Protein 57 g

*NUTRITION INFORMATION IS PER 100 GRAMS OF DRY BUG

BUG ILLUSTRATIONS BY BROWN BIRD DESIGN; SOURCES: "NUTRITIONAL COMPOSITION AND SAFETY ASPECTS OF EDIBLE INSECTS," B.A. RUMPOLD AND O.K. SCHLÜTER, MOLECULAR NUTRITION & FOOD RESEARCH, MARCH 2013

insects have been grown for decades as fish bait and food for pet reptiles. To see how crickets are raised for people, last November, I took a trip to Big Cricket Farms in Youngstown, Ohio, the first food-grade cricket operation in the US.

The farm resides in a former vegetable co-op, a 450-square-metre warehouse tucked in the back of a parking lot. Kevin Bachhuber, Big Cricket's co-founder, had promised I would hear the chorus of breeders—mature crickets capable of reproducing—but when I stepped inside, I met only silence. A crisis of unknown origin had killed more than a million breeders weeks before my arrival. Luckily, I missed the direct aftermath: the deathly smell of 400 kilograms of rotting cricket corpses. "It was like a little genocide," Bachhuber said.

He and the company's cricket wrangler, Luana Correia, led me away from the empty breeder boxes to the nursery, split into two black tents. We pulled sanitary disposable booties over our shoes, unzipped a door, and stepped into an oppressive heat—the tents are kept at 32 degrees Celsius and 90 per cent humidity to nurture the young. It smelled like roasted nuts. Plastic boxes lined the walls, and Correia pulled one down to show me an egg carton inside. It teemed with uncountable baby crickets, nicknamed pinheads, the features on their fragile bodies nearly imperceptible. The tents hold three to four million in total. If they all grow to adulthood—unlikely, as pinheads are prone to accidental squashing—they will amount to 1,350 kilograms of cricket meat, or 350 kg of protein powder. By harvesting the adults every seven weeks, Big Cricket projects it will grow 27,000 kg of crickets annually, and Next Millennium Farms, even more: up to 135,000 kilograms a year.

The fledgling industry poses an interesting conundrum to government agencies. Like larger livestock, crickets are subject to federal and state regulations. Until the relevant agencies can sort out the finer points, both they and the start-ups they regulate have been collectively winging it. Or caught on the hop. Or [*Snip - Ed*]. When Big Cricket Farms had to rebuild its stock after the mass death of its breeders, Bachhuber followed US Department of Agriculture (USDA) organic chicken egg rules to decide whether eggs from a pet-grade cricket farm can be hatched for human consumption, for example. The FDA and the Ohio State Department of Health simply require a guarantee that

food-grade crickets are farm-raised rather than wild-caught to avoid pesticides and other unintentional contaminants. And as of now, the USDA has no plans to inspect cricket farms and likely won't unless there is an obvious and widespread health problem or they begin producing amounts comparable to

of operations of a start-up," Bachhuber told me, "is that your stress levels will never be higher."

Big Cricket got its start through the Youngstown Business Incubator, and at the end of my visit to Ohio, Bachhuber and I headed to the former furniture store it occupies across town. A conference room had been set up for

"THE ULTIMATE GOAL IS GOING TO A RESTAURANT WHERE YOU CAN GET A CHICKEN BURGER, VEGGIE BURGER, OR **ENTO** BURGER."

beef and other meat, says Sonny Ramaswamy, director of the National Institute of Food and Agriculture. That's not likely anytime soon: Americans alone eat about 11 billion kilograms of beef a year. Aussies eat about a billion.

Although crickets are unlikely to transmit illnesses like mad cow disease or swine flu, they do get sick, and that is perhaps the trickiest part of the business. Big Cricket Farms chose the European house cricket, *Acheta domestica*, for its taste and nutritional profile. But the species is prone to cricket paralysis virus, which can whip through a farm and leave 95 per cent of the insects dead. It's also the only farmed cricket subject to a less contagious picornavirus, which I later learned may have caused the die-off at Big Cricket. The company subsequently switched to a hardier stock: the tropical house cricket, *Gryllodes sigillatus*. It also began researching a receiving room that would disinfect new shipments of eggs or crickets with virus-killing ultraviolet light.

"The nice thing about being in the first year

a small reception, and a long table held typical party fare: platters of cheese and hard sausage, veggies with dip, chips, and crackers. At the end of the row sat one bowl of homemade cricket pesto and another with whole crickets sautéed in garlic. The pesto looked like any other, and I spooned some on my plate. But the crickets—there was no abstraction here. These had eyes, antennae, and legs. *If this is the future, might as well see what I'm in for*, I thought.

I can't say the crickets went down smoothly. I had to drown them in pesto and shovel them in with a cracker. It was an eating experience reminiscent of childhood, when my parents made me take just three more bites of an unfamiliar food before I could leave the table. As then, I did so warily, willing my tongue and teeth not to explore. I'm no picky eater these days, but if consuming whole insects is the eventual goal, I think it will take a while to convince the Western palate. But that cricket pesto? Washed down with a cricket bitters cocktail? That, I'd have weekly. 

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THE CHURCH

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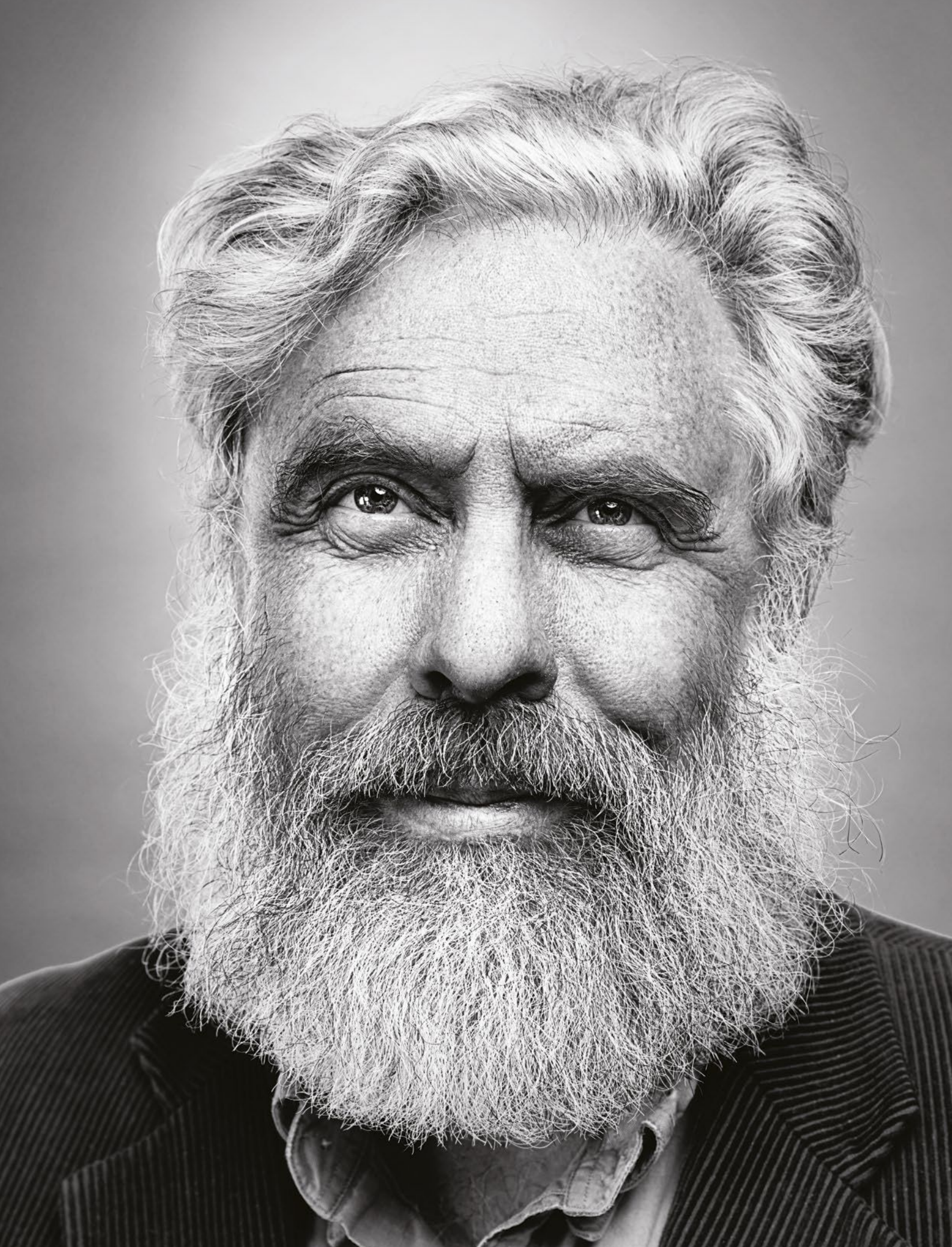
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CAN A SINGLE SCIENTIST
TRANSFORM THE FIELD OF BIOLOGY—
AND OUR LIVES?



The Church of Church



A few years ago, George Church was peer-reviewing a paper for the journal *Science* when he got an idea. The paper's authors had encoded their names and a string of famous quotes into a bacterial genome to demonstrate the power and possibility of synthetic biology, the design and manufacture of DNA in a lab. Their encoding method was good. But Church, a genetics professor at Harvard Medical School, thought he could do better.

Sitting at his desk, in the space of a few minutes he wrote a computer program that translated his review from Roman letters into binary code and then into genetic code. He submitted the review to the journal's editor, who couldn't read it. The document contained only As, Ts, Cs, and Gs, shorthand for the nucleotides in DNA. The editor passed it along to the study's authors. "At first, they had no idea what it said," Church says, chuckling.

That should have been the end of it. The paper was published, and the stunt passed quickly into the stock of Church lore, in league with the time he lived for a year on nutrient broth from a lab vendor or the time he wore homemade blinders around the lab to make a statement about tunnel vision.

But Church wasn't done. He wanted to see how far he could take his computer program, so he began looking for something else to code, something larger than a single review. He settled on his own book, *Regenesi*, which was about to be published. He spent a few days adapting the program he'd written and converted all 350 pages of text and photos into a string of As, Ts, Gs, and

Cs. In the lab, he synthesised a strand of DNA to match the code, replicated it many times over, and dabbed a drop of the synthetic DNA onto a scrap of paper. The dot contained 70 billion copies of the book. It was no bigger than a period.

A few months later, Church took his experiment with him on *The Colbert Report*, pulling out the paper scrap—about the size and shape of a fortune cookie

**CHURCH IS HELPING TO
FORGE A NEW KIND
OF BIOLOGY, ONE LESS GEARED
TOWARD STUDYING DNA
THAN HARNESSING IT FOR
OUR OWN AIMS.**

slip—for the world to see. Before he knew it, representatives of several companies tasked with archiving films and recordings were knocking on his office door.

"They said, 'We want to do data storage,'" Church tells me. "I said, 'You guys realise this is super academic, right? There's no company or anything.' And they said 'Yeah sure, but data storage is a big problem.'"

With that, his parlour trick sprouted into a business. Members of Church's lab are now scaling up the process in order to encode just about any form of media into DNA. If they succeed, they will have not only revolutionised data

storage but ushered in what is perhaps biology's most exciting era: the era when our capacity to manipulate the basic code of life dwarfs the capacity of even our most advanced computers.

Church tells the story pretty calmly, considering. We're sitting in his office, a generous space tucked into the side pocket of a large lab, with windows that look down on Boston's Longwood Avenue. He's leaning back in his too-small office chair, stretching his legs out in front of him (he's six-foot-five) and occasionally tugging at his Darwin-esque beard. He has blue eyes, a kind face, and an even voice, none of which betray the excitement or manic brilliance that one assumes must fuel such breakthroughs. If anything, he seems entertained. This is an amusing anecdote. The rest is an aside.

Church has already transformed biology once before. The DNA-sequencing technology he first devised in graduate school helped reduce the cost of whole-genome sequencing from billions of dollars to thousands. Scientists are now using it to investigate intractable diseases, such as cancer and schizophrenia, and doctors are beginning to use it to identify genetic mutations that cause rare illnesses that often defy diagnosis.

Amid the bays and bench tops that constitute Church's laboratory, a litany of other revolutions are taking shape: His team of researchers is coaxing the woolly mammoth back from extinction by melding its genome to an elephant's. They're devising ways to inoculate mosquitoes (and, by extension, us) against malaria. And they're designing tools to help physicists hunt down dark matter and to help neuroscientists map the human brain. Church has launched 15 bioengineering start-

ups in the past decade and advises a number of others. More so than any other scientist in his field, he is helping to forge a new kind of biology, one less geared toward studying DNA than harnessing it for our own aims.

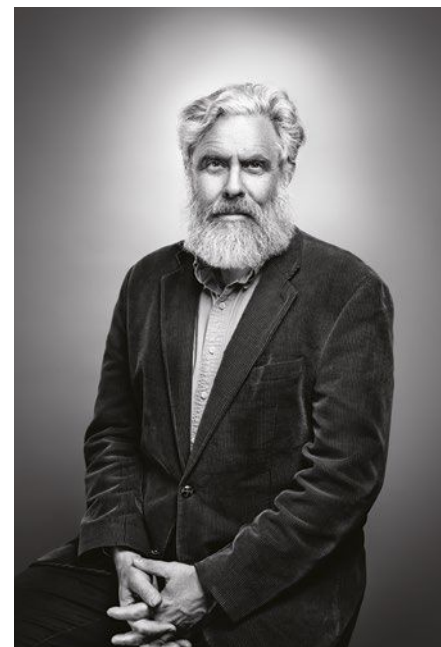
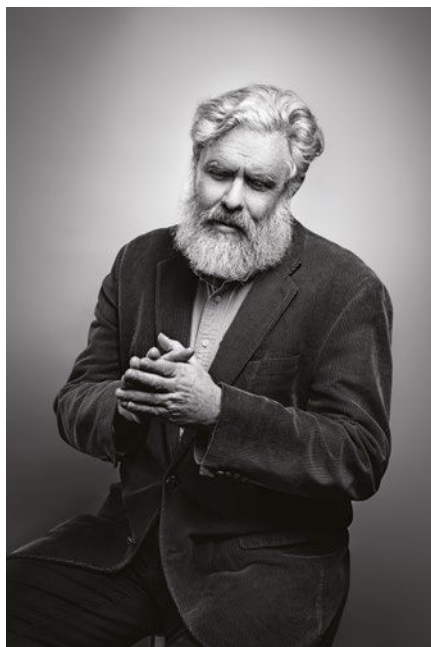
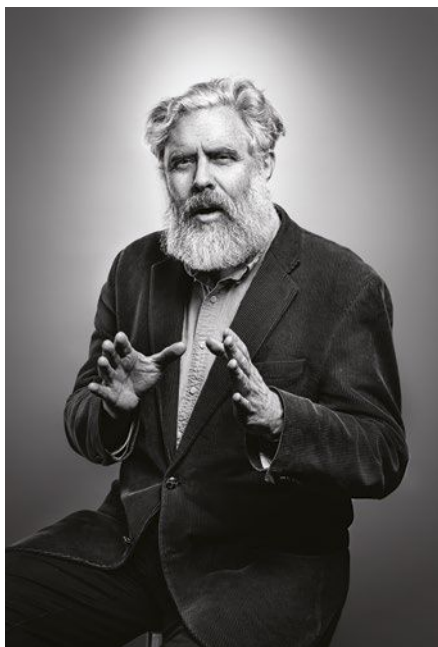
In the book that he encoded in DNA (which, incidentally, is also available printed and bound), he and his co-author, Ed Regis, envisioned the future this new biology could bring, one in which bacteria fuels cars and commercial jets and humans are immune to cancer. It may sound like

science fiction, or at least like a litany of over-hyped pipe dreams that science so often sells. But George Church's pipe dreams have an uncanny record of becoming reality.

• • •

For all his eccentricities, Church is an easy person to talk with. And yet such is his reputation for brilliance that people seem always to be apologising to him for their own intellectual shortcomings. "I'm sorry if this sounds stupid," people say. I caught a reporter doing it, and a CEO. Then, I did it too.

In fact, on my first visit to his office, I manage to completely embarrass myself. It's early afternoon, and he's invited me to sit in on a telephone interview with a radio reporter, before I tag along to some meetings. A handful of 3D-printed molecules are scattered across the big round table in the centre of his



At Harvard, Church attacks many of the world's hardest problems with genome editing.

office. He has been fidgeting with one—distractedly pulling it apart, between his thumb and forefingers before letting it snap back together—while he leans back in his chair and talks at the speakerphone. I pick up another molecule, one that looks identical to his but is not. Instead of snapping back together when I pull at it, it explodes.

Twelve plastic pentagons and one large white die go flying through the air. They skittle loudly across the table and roll onto the floor. Some of them land under Church's desk. I am mortified. I scramble to gather all the pieces and reassemble them as quietly as possible, while he calmly continues to answer questions about genomic medicine.

When the phone call ends, I make sheepish apologies. "I thought by the way yours was snapping back together ..." I say, trailing off into the ether.

Unfazed, he takes the two molecules, holds them side by side, and launches into a geometry lesson. They are both dodecahedrons, he explains—objects with 12 sides. He has rigged his with some putty to prevent the pieces from disassembling; mine has not been so rigged. It is also wrapped around a 20-sided die, or an icosahedron. "I found this die on the street," he says. "I like it because it looks like the nuclear material of a virus." He goes on to explain the significance of these shapes: Icosahedrons are among the most symmetrical structures in the natural world, he says. They also form the basis of viral symmetry. I pretend to understand, but my takeaway is simpler than he probably intends: George Church is the kind of guy who finds a 20-sided die and immediately thinks about the structure of viruses.

He has been tinkering like this—testing the ways in which the world around him does and does not fit together—for most of his life. When he was 10 years old, he began replicating the work of a botanist named Luther Burbank by grafting the branches of one fruit tree onto another in his backyard. As a teenager at Andover, a private school, he taught himself BASIC computer

programming and then taught the school's computer linear algebra. As an undergraduate at Duke University, he raced through the curriculum and simultaneously completed two bachelor's degrees (in zoology and chemistry) in two years. As a graduate student there, he helped solve the structure of transfer RNA, which translates the nucleic acids of DNA into the amino acids of proteins. He spent so much time in the lab that Duke expelled him from its PhD. program for missing too many classes. Fortunately, Harvard took him in.

"It was pretty clear he was a different sort of bird right from the beginning," says Gary Ruvkun, a Harvard geneticist and good friend of Church's (the two attended graduate school together). "I still remember I would work late, and when I'd be leaving the lab at, like, 0200h, he'd be buzzing in on his bike, ready to start the day."

It was at Harvard that Church met his future wife, a fellow graduate student named Ting Wu. He followed her across the country and back before the couple settled in Boston to grow their labs (both at Harvard) and their family (they have one daughter, now in her 20s). His wife, he says, is a much better geneticist than he. In fact, Church is fairly adamant that he's not a scientist at all but an engineer who occasionally does some science.

Like an engineer, he tends to see

the universe not as a disparate set of mysteries but as a machine with a vast array of buttons and levers, each begging to be pushed and pulled. "His approach to science is modelled after the home-brew computer clubs, where the computer revolution was started in basements and garages," Ruvkun says. "He told me once that he's more proud of his National Academy of Engineering membership than of his National Academy of Sciences one. Nobody else I know thinks that way."

• • •

Here's how it goes in most academic laboratories: A scientist develops proficiency in a handful of techniques and uses those techniques to study a handful of closely related questions. That lab attracts students and junior researchers with narrowly aligned interests and experiences. The entire system tends toward specialisation, so that, by and large, molecular biologists interested in immunology and experienced with mice go to one kind of lab and neuroscientists interested in the visual system and experienced with flies go to another. Expertise is cultivated and refined and, in some cases, hoarded like wartime food rations.

Church's lab is the opposite. Rather than seeking homogeneity, he recruits as

The Church of Church

diverse a group as possible. Physicists and neuroscientists work alongside geneticists, engineers, and entrepreneurs. “The image for me is of poking deep holes all over the place, in the fabric of science and engineering,” he says. “As we probe each of those points, we get cross talk.”

The result is that his lab manages to be both one of Harvard’s top producers and a well-known receiving centre for science’s misfit toys. There’s an artist encoding Wikipedia entries into apple genomes (to create a literal tree of knowledge) and an insurance industry refugee who fled his office job over a decade ago, worked several months for free while teaching himself biochemistry, and now serves as “co-head” of the lab. For a time, there was also a passenger-pigeon obsessive who had no advanced degree but had heard about Church’s mammoth de-extinction project and cold-called asking to participate; he has since gone on to lead the pigeon resurrection initiative out of a lab in California.

“We always joke that the only thing you need to do to join George’s lab is show up,” says Uri Laserson, a former student of Church’s and the co-founder of Good Start Genetics, a company that offers genetic screening for inherited diseases. “There is zero organisation. His style is just to let things happen.” It’s a scrappy kind of place, Laserson says—a little bit sink-or-swim—but not in a bad way. “Mostly, you have the constant sense that exciting things are happening or are about to happen and if you miss out on it, you have only yourself to blame.”

The projects that emerge from this controlled chaos seem to fall along a continuum. At one end, the lab applies biology to very specific non-biological problems. Data storage is an example, but lately, members of Church’s lab have been using DNA to help physicists track dark matter, a mysterious substance that makes up some 27 per cent of the known universe. At the other end of the continuum, Church’s team employs the tools of other sciences to solve the problems of biology. For example, the newly developed technique FISSEQ (fluorescent in situ sequencing) draws on a few different subsets of physics to help geneticists visualise gene expression in living cells. Before FISSEQ, scientists could measure just three or four genes at a time; now, they can measure

thousands at once.

But it’s the projects in the middle of the continuum—biology-based solutions for biology-based problems—that tend to garner the most attention. Many of these involve CRISPR, a genome-editing tool derived from bacteria that uses an enzyme to excise specific nucleotide sequences and swap them with others. With it, scientists can alter multiple genes at once, without having to do the arduous work of extracting, isolating, and cloning the original genetic material and cross-breeding the resulting transgenic animals. A few other tools offer a similar shortcut, but CRISPR is much quicker. “It’s the fastest thing I’ve seen yet,” Church says. “It’s like you throw a piston into a car and it finds its way to the right place and swaps out with one of the other pistons—while the motor’s running.”

In January 2013, Church was one of the first to show that CRISPR could splice DNA in human cells. Since then, scientists have used it to correct a number of genetic problems, including certain forms of liver disease (in mice) and antibiotic resistance.

Church says CRISPR can address ecosystem-level issues as well. By circumventing the rules of sexual selection with live genome editing, CRISPR greatly increases the odds that

that species within a few generations.

CRISPR is also a key component of what may be the most high-profile of Church’s projects: de-extinction. When Stewart Brand, editor of the famed *Whole Earth Catalogue*, hatched a plan to revive extinct species such as the woolly mammoth and the passenger pigeon, he turned to Church for the technology. Church devised an automated genome-engineering process (called the “evolution machine” by some) that enables researchers to meld together genomes from different species. His lab is now at work on a “cold-resistant elephant”—an elephant that has borrowed genes from the woolly mammoth so that it can thrive in colder environments. It could be possible to resurrect other species using the same approach, Church says. In fact, the possibilities are as limitless as our imaginations.

Whether that’s a promise or a peril depends on whose imagination we’re talking about.

• • •

Before Church broke out the 70 billion copies of his book on *The Colbert Report*, the comedian asked him a question he gets a lot. “How do you think your work,” Colbert asked, “will eventually destroy all mankind?” The audience laughed riotously. “Do you think it’s going to be like a killer virus,” he asked, pausing to lean in and tap his fingers on the table. “Or more like a giant, mutant, killer squid man, who arises from the Pacific, between Easter Island and Chile, and feasts on our flesh?” Although it was a joke, the bit underscored a paradox that Church often faces in response to his work. On one side, there are sceptics who don’t believe the possibilities Church is peddling. On the other side, there are terrified believers who worry that it may be all too possible.

Church tends to view this paradox through the same lens that he views most everything: as an engineering challenge. Take gene drives, for an example. Terrified believers worry

about what could happen if a given gene drive has unintended effects. Say scientists introduce a gene that makes mosquitoes resistant to malaria, but that in turn causes an unexpected crash in the mosquito population that throws the ecosystem out of whack. Church’s response to such a disaster would be simply to deploy a reverse drive to try to undo the damage. Sceptics have a different set of concerns, namely that natural selection would just weed out the new gene

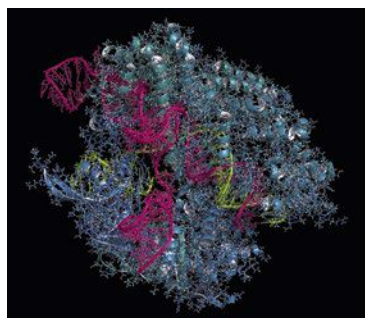
over time, making gene drives unworthy of the effort and risk. To this, Church just says we could deploy the same drive periodically, making slight tweaks here and there.

To play either of these scenarios forward is to see the world through Church’s eyes: a place where DNA is the ultimate computer code and we are all computer programmers.

Of course, not all concerns are technical. Animal rights activists worry about a surge in animal experimentation now that CRISPR has made it easier than ever to create, for example, genetically modified monkeys. And corporate watchdogs have their own concerns about placing control of the

**“THE WORLD WIDE WEB WENT
FROM ZERO TO MILLIONS OF WEB
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a given gene will be passed from parent to offspring. The result is what scientists call a gene drive: That is, a gene is driven quickly through an entire wild population. Imagine that you insert a gene for malaria-resistance into a single mosquito and release that mosquito into the wild. You may eventually wipe out the disease altogether. Or imagine inserting a gene that renders an invasive species sterile. You could potentially rid an ecosystem of



The Most Important Technology in Biology Today

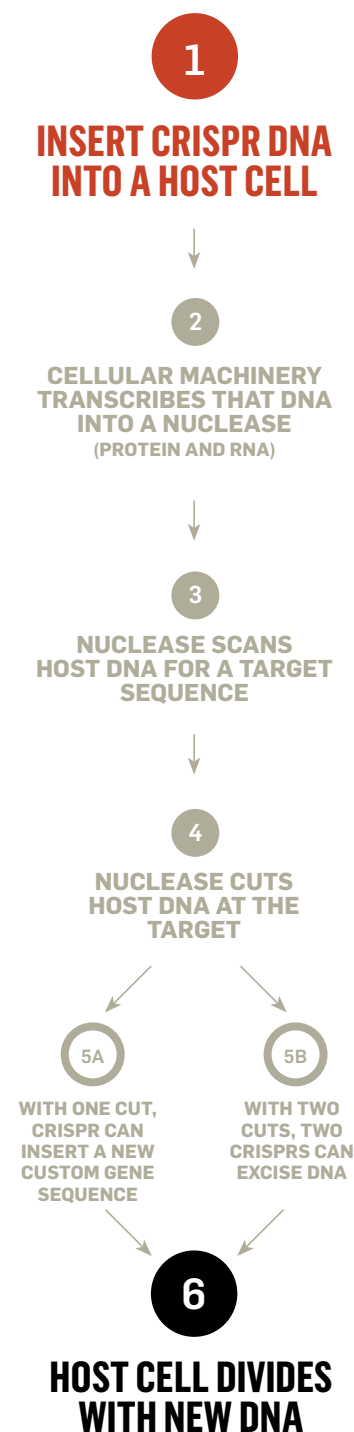
GENOME EDITING IN SIX EASY STEPS



A tool called CRISPR could herald the start of a revolution in genetic engineering. But to understand why takes some doing. Bear with us. Modifying genes used to require a painstaking process: Scientists would kill a cell, extract the DNA, manipulate it, and then reinsert it. Several tools now provide a shortcut, and CRISPR is the most efficient. Its protein complex swaps a targeted genetic sequence with another, allowing scientists to engineer DNA in living cells with unprecedented speed. Using CRISPR, scientists could modify genes to prevent disease, slow aging, bring back extinct species, even develop new fuels. The possibilities are almost limitless. **JUNNIE KWON**

human genome in the hands of private for-profit companies. It bears stating that Church works with a number of corporate sponsors, including Chevron, Procter & Gamble, and Merck.

Church makes no apologies for his entrepreneurship. He nearly always



opens his lectures with a slide that displays all the logos of the companies he's affiliated with. He agrees that there are risks involved in the work he does, but he does not think that vilifying corporations is the answer. "Industry is an essential part of what we do," he says.

"You can't just hoard your ideas inside the ivory tower. You have to get them out into the world."

Still, he takes safety concerns seriously. Last summer, Church and a few colleagues published two papers and one blog post on the same day, introducing the concept of gene drives and calling for "informed public discussion, regulatory review, and the establishment of guidelines for the safe development of the technology." No one had actually made a gene drive yet, but Church wanted to get the ball rolling. "The important thing is to actually listen to the public's concerns," he says. "And then try to visualise things that can go wrong and think of ways to guard against them."

To that end, he is devising new methods of bio-containment; the term normally refers to the physical safety measures (cabinets, hoods, isolation rooms) that laboratories use to prevent the escape of potentially dangerous organisms. In January, Church and members of his lab reported in the journal *Nature* that instead of relying on physical containment, they had managed to install protective measures within the microbial genome itself. They engineered a strain of bacteria that survives on a synthetic amino acid found only in the laboratory, not in nature.

And that's how Church the engineer works. No obstacle is insurmountable. Technology moves toward greater efficiency and capacity, he says, not the reverse. And in any case, doubters come with the territory. "The World Wide Web went from zero to millions of web pages in a few years," Church says. "Many revolutions look irrelevant just before they change everything swiftly."

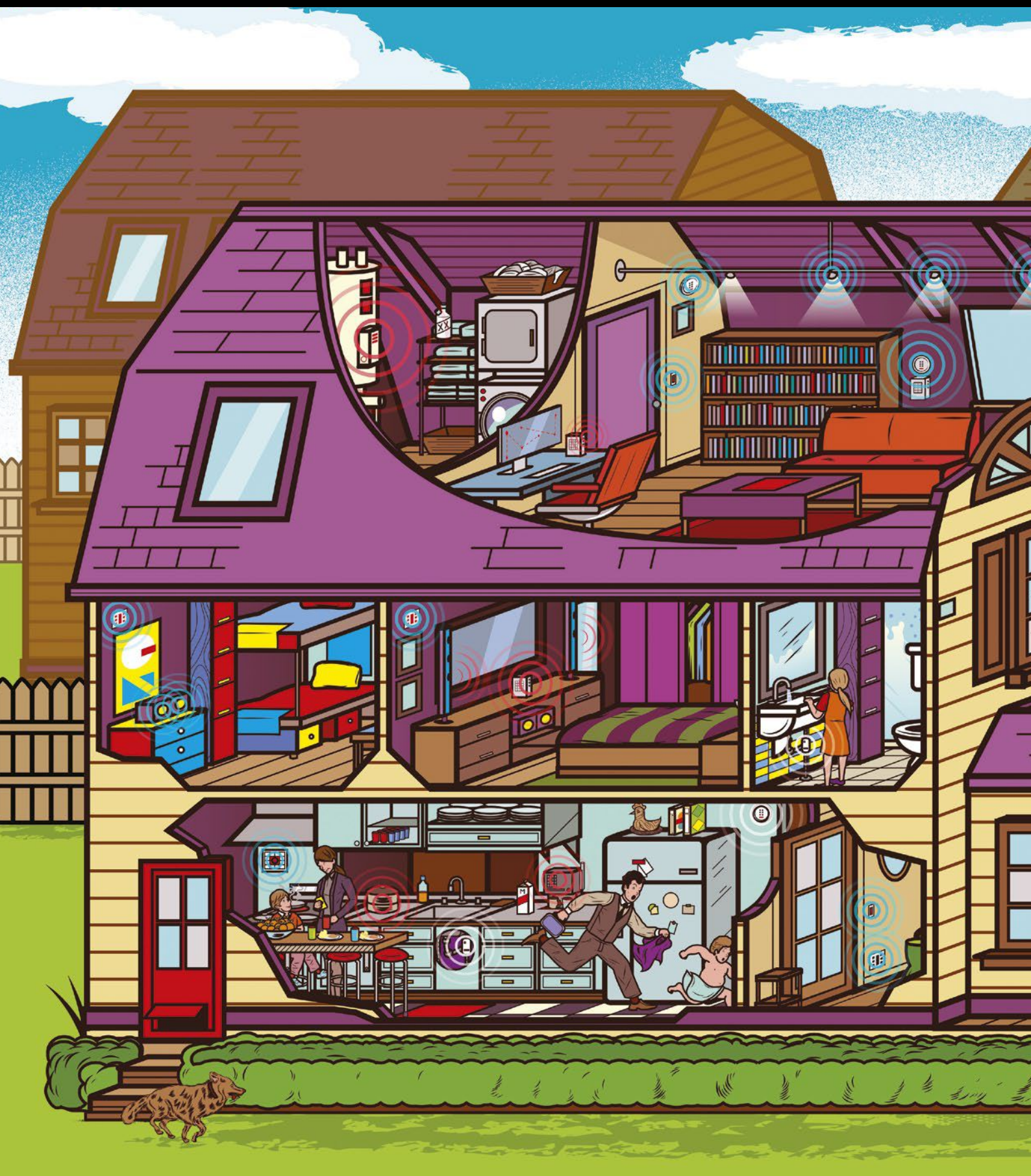
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The last time I chat with Church he is on a mobile phone, walking from his office to a meeting down the street. The connection's crackly, so I ask whether he'd prefer to talk later. "I like talking and walking," he says. "It's more productive than doing just one."

I ask for an update, and he rattles off a string of developments. The company funding his data-storage project is planning to make a big announcement about his team's latest advances. "We've scaled way up from the five megabyte book," he says. He's got a paper due out in the *Proceedings of the National Academy of Sciences* about the DNA and dark matter project. His group has also completed the first successful gene drive, a small pilot study in yeast that proved that foreign genes introduced to cells in a lab can be passed on to—and spread throughout—a separate wild population.

I ask him which project he's most excited about. He answers without hesitation: CRISPR. "I like exponential fields," he says. "Right now, nothing is more exponential than that."

Church has helped launch Editas Medicine, a biotech company aimed at harnessing CRISPR's therapeutic potential. The idea is to develop a new class of CRISPR-based drugs that can "surgically repair" aberrant genes. Editas has plenty of financial and scientific backing, but it's still in early days. More than most, Church knows that ideas can often be ahead of their time. On more than one occasion, he has had to shelve a project—low-cost gene sequencing, for one—until the rest of the world was ready for it. "People think it's great to be ahead of your time," he says. "But it can actually be quite painful." We should all be grateful that's never stopped him yet. **P/S**



THE HACKER'S GUIDE TO

SMART HOMES

HOW TO MAKE YOUR HOUSE INTELLIGENT, EFFICIENT, AND WAY MORE FUN!

BY CORINNE IOZZIO

S

Sure, we've heard a lot about smart homes and how they're the wave of the future. Yet that future has always seemed just over the horizon. But now several home-automation platforms have emerged that give Internet-connected devices—gizmos like lightbulbs, outlets, thermostats, and motion sensors—something they lacked: the ability to communicate with one another. With that, devices can take coordinated action to save you time, money, and labour. So what are you waiting for? Here's how anyone can make a dumb house into a truly intelligent home.

STEP
1

PICK YOUR PLATFORM

Different products can cause chaos when they don't communicate. So choose a platform that uses a networking hub or an app (or both) to marry disparate devices and give your house a centralised brain from the get go.



For the Keyboard Banger

Belkin WeMo

Most WeMo devices can connect to an app right out of the box, no tinkering required. But simplicity brings limitations—there are only 14 products to choose from. (www.belkin.com)



For the Weekend Webmaster

Wink

Wink uses a hub and a smartphone app to connect unrelated brands and devices, bringing more gadgets—think locks and self-closing blinds—into the fold. (www.wink.com)



For the GeniusBar Nerd

SmartThings

With 150 third-party products, this hub-and-app system accommodates plenty of gadgets. Users can also design their own interactions. The trade-off is a trickier setup. (www.smartthings.com)

STEP
2

SWAP YOUR FIXTURES

The core of a smart home is the ability to monitor and remotely control power, lighting, and security. That means replacing—or upgrading—everyday household fixtures, such as power points and bulbs, and installing environmental sensors that will let you monitor what happens around the house.



Lightbulb

Cree Connected LED

Cree eliminated the heat sink typical of most LEDs, cooling its bulbs through a series of vents. Its design gives the bulb an omnidirectional shine—just like its incandescent forebearers.



Electrical Socket

Quirky+GE Outlink

Disguised as an everyday pair of outlets, the socket has one smart and one dumb receptacle. That means you can remotely kill power to the coffeepot without tripping the fridge.



Water Sensor

Belkin WeMo Water

This sensor monitors an entire house's water usage from a single point. When clamped onto a pipe, a pressure sensor detects subtle shifts—from an open tap to a costly leak.



Door Lock

August Smart Lock

The clever kit fits over an existing deadbolt, so there's no need to replace the entire lockset. Once installed, you can issue guests digital keys or set the lock to open as you approach.



Smoke & CO₂ Alarm

First Alert ZCOMBO

The ZCOMBO alarm not only sends emergency alerts, it triggers other devices in your network. For example, during a fire it can raise the lights so you can find your way out.



Doors & Windows

SmartSense Multi Sensor

A pair of mounted magnets can tell whether doors, windows, or even mailboxes are open. The sensor can also cue common tasks, like stopping the AC if you open a window.



Environment

Quirky+GE Spotter UNIQ

The Spotter senses up to six environmental cues: motion, vibration, sound, temperature, humidity, and light. It can turn on hall lights as you approach or alert you when the dryer stops.



Light Switch

Belkin WeMo Light Switch

Until there's a smart-bulb equivalent for every light, connected switches imbue otherwise dumb fixtures with brains. The app also lets you sync lights with sunrise and sunset.



Security Camera

Dropcam Pro

With a 130-degree field of view, 8x zoom, and infrared night vision, the Dropcam Pro's unblinking eye allows you to peek inside your home without racing to the scene.

COMING SOON!

VOICE CONTROL

Clever DIYers have rigged smart homes to respond to commands from Siri and other voice assistants. Apple made the connection official. Starting this year, manufacturers can now use Apple's HomeKit system to make their products react to commands dictated to an iPhone. For instance, "Siri, I'm heading home" could turn on lights, adjust the temperature, and start the stereo.

STEP
3

CONTROL YOUR CLIMATE

All smart thermostats share a common goal: save money while the homeowner stays comfortable. An Internet connection allows them to adjust the indoor temperature based on outdoor conditions—some even factor in humidity. But the best way for a home to adapt to its residents is still up for debate. Your schedule may dictate which method is best for you.

If you have a regular routine ...

The Nest Learning Thermostat uses algorithms to learn from your patterns. The device monitors when you change the temperature and builds a schedule. Eventually, Nest takes over, so when you wake up or arrive home, the house will already be at your ideal temperature. Recent studies have found that using Nest can save up to \$145 annually.

If you come and go a lot ...

The Honeywell Lyric Thermostat shifts its energy-saving mode based on whether there are people in the house. Family members give Lyric access to their whereabouts via a smartphone app. When they pass a geofence, a preset distance that can range from 150 metres to 10 kilometres, the system toggles on or off. This could cut annual costs by up to \$220.

STEP
4

AUTOMATE

After setup, you can teach the smart home to think for itself, freeing you from using an app every time you want to change the temperature or turn on the lights. That means creating automated actions; because each platform can talk to all the gadgets you have online, they can suggest scenarios and guide you through the setup process. Here are a few examples of what your smart home can do:

Schedule Method

Create standard operating procedures signalled by specific times of day.

Sunset. Action: Close blinds and increase interior brightness by 50 per cent.

2100h Action: Cut power to playroom TV.

Tuesdays 1300h Action: Allow cleaning crew inside.

Stimuli Method

Triggers take input from a sensor (or sensors) and translate it into an action to be carried out by another device.

Movement in the bedroom after 0600h.

Action: Power on coffee machine.

Opened living-room window.

Action: Turn off AC and turn on floor fan.

Homeowner leaves house.

Action: Lock the door and lower the thermostat.

DUMB SMART

A few so-called smart appliances are conspicuously absent here because we've set the bar high: Devices must not only connect to the Internet but also to one another, creating a network of shared data and automated tasks. Two categories that are not ready:

TVs: Their smarts consist only of an Internet connection and the ability to stream media from Netflix, Pandora, and the like.

Large appliances: Ovens, washers, dryers, and refrigerators will be the next wave of smart items, but today, they're still learning the ropes. Prototypes do show promise: Whirlpool, for example, is developing a dryer that will shift into a slower cycle if you're not home to empty it.

...JUST PLAIN DUMB

Adding intelligence doesn't always make an object better, says Matt Rogers of Nest Labs. So we asked him: What's best left alone?

Mirrors: Too niche

"What's the good of having your mirror filter out gray hairs or count your brush strokes? Unless you're the Wicked Queen, this is not a problem."

Toasters: Unsafe

"When you're three years old, mothers are supposed to teach you to turn all that stuff off when you leave the house."

Sofas: Missing the point

"Imagine the couch telling you that you've been sitting on it too long and that you've put on a few."

STEP
5

ADD SOME KICKS

Finally, not all smart-home devices are needed—some get by because they add frills (or fun) to our lives.



Crock-Pot Smart Slow Cooker

A six-hour recipe and an eight-hour workday don't mesh; thankfully, you can start, stop, or turn down this cooker via mobile.



Jawbone UP24

Not only can this activity tracker alert your house when you come and go, but it also knows when you're asleep. Nod off and it'll turn off the lights.



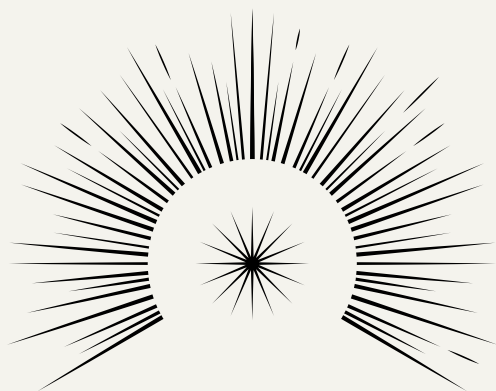
Sonos PLAY:1

Sonos speakers respond to triggers from in-home sensors. If you want your stereo to play "Welcome to the Jungle" whenever you walk in the door, Sonos will.

IN THE WORKS!

ARTIFICIAL INTELLIGENCE

Machine-learning algorithms in products like the Nest thermostat are only the beginning of a self-automating home. Soon, apps might recommend tasks based on patterns—"I see you turn on the lights at the same time every day, shall I schedule this task?" But the ultimate goal is autonomous artificial intelligence, where you'd buy a product and your home would figure out the rest. For now, SmartThings founder Alex Hawkinson says, "We're probably years from saying 'I'm gonna go live my life and let the tech figure itself out.'"



Nothing but the Truth

SCIENCE'S GREATEST
WEAKNESS IS ALSO ITS GREATEST
STRENGTH

BY **Alan Lightman**



Alan Lightman is a physicist, novelist, essayist, and educator at the Massachusetts Institute of Technology and a finalist for the US National Book Award.

F

Forty years ago, the legendary physicist Richard Feynman gave the commencement address at my graduation from the California Institute of Technology. It was a boiling day in June, and we graduates—all budding biologists and chemists and physicists—sprawled in folding chairs on the lawn, sweltering in our black gowns. Feynman told us that before we went public with new scientific results, we should consider every conceivable way we might be wrong. It was a tall order.

A recent case in point was the discovery, in March 2014, of evidence that purportedly confirmed the theory of inflation. According to the theory, proposed by physicists Alan Guth, Andrei Linde, and others in the early 1980s, the universe briefly inflated at an exponential rate when it was about one trillionth of a trillionth of a trillionth of a second old. It then slowed to adopt the more leisurely expansion predicted by the standard big-bang model. The theory of inflation naturally explained a number of observations not easily accounted for by the big-bang model, and it has been almost universally accepted by practicing cosmologists ever since.

But science places more value in predicting new phenomena than it does in explaining results already known. Years ago, the theory of inflation predicted a particular twisting pattern in the vibrations of the radio waves that pervade outer space, the so-called cosmic background radiation. Scientists studying three years' worth of data from the BICEP2 observatory at the South Pole found such

a telltale pattern last spring. The team involved more than 50 scientists and was led by John Kovac of the Harvard Smithsonian Centre for Astrophysics. The story immediately went viral. In a press release titled "First Direct Evidence of Cosmic Inflation," Kovac said, "Detecting this signal is one of the most important goals in cosmology today." A YouTube video posted by Stanford University shows one of

its objective pursuit of truth often cannot be found in the work habits of individual scientists. It's manifest only in the combined efforts of the scientific community, with researchers constantly testing and criticising one another's work. Individual scientists are driven by the same passions and biases and emotional attachments as non-scientists. Most try their best to be objective, but, as Francis Bacon, one of the



PASSION IS A DOUBLE-EDGED SWORD,
ONE THAT CAN BESTOW BOTH FORTUNE AND
MISFORTUNE UPON THOSE WHO WIELD IT.

the team members excitedly telling Linde that they had found "the smoking gun of inflation," after which they celebrate the success with a bottle of champagne, no doubt anticipating Nobel Prizes.

Then in January, another team of astronomers, using data from the European Union's Planck satellite, announced that the twisting pattern was not actually caused by exotic processes at the birth of the universe. Instead, it was produced by galactic dust. It's not that the Kovac group did sloppy work. Rather, the scientists had failed to follow Feynman's advice. In their ardour to confirm what would have been one of the greatest scientific discoveries of the century, they had not sufficiently considered the possible competing effects of galactic dust—effects that other scientists had worried about at the time.

The history of science brims with similar cases, where eager scientists leaped to press too soon. One need only remember the 1970s-era anticancer drug Laetrile, which supposedly destroyed tumours; the reported discovery in 1975 of "magnetic monopoles" (magnets with either a south pole or a north pole but not both); and the reported achievement of cold fusion in 1989. Other scientists later disproved every one of these claims.

In fact, professional historians and philosophers of science know a dirty secret. The much-vaunted "scientific method" and

fathers of the scientific method, said four centuries ago, "The human understanding is no dry light but receives infusions from the will and affections."

This year, in particular, it would be wise to keep Bacon's warning in mind. In March, the world's most powerful particle accelerator, the Large Hadron Collider (LHC), came back online after a two-year hiatus and an upgrade that doubled its energy. In 2012, the LHC helped scientists find the long-sought Higgs boson. This year, it could do the same for dark matter, a mysterious and still unobserved subatomic particle believed to make up about 27 per cent of the universe. Elsewhere, physicists are mounting at least four major experiments to confirm the existence of dark energy, a similarly unobserved substance theorised to create a kind of negative gravity that causes space to expand at an accelerating rate. Astronomers are getting their first good looks at the comet 67P/Churyumov-Gerasimenko and the dwarf planets Pluto and Ceres, all of which could yield clues about the formation of our solar system. And the hundreds of biologists and neuroscientists involved in the Human Brain Project in the EU and the BRAIN Initiative in the US will be investigating the riddles of brain function more deeply than ever before. Evidently, we may be in for another year of irrational exuberance.

And yet that may not be so bad. Exuberance carries its share of risks, certainly, but I would argue that it's also essential to the enterprise of science. Without personal investment and passion, most scientists would not struggle with their research projects for months and years as they do. They would not stay up all night in their labs as they do. They would not endure the tedium and strain and constant possibility of failure or dead-end results. I remember well my days and nights working in astrophysics, thinking about my current research problem nearly every minute of the day, sometimes eating meals of peanut butter at my desk so as not to interrupt my feverish calculations. All my energy, my thoughts, even my personal identity and self-worth hung on those calculations.

Science would not proceed without such devotion. And there is the irony. Passion is a double-edged sword, one that can bestow both fortune and misfortune upon those who wield it. Passion is the stuff that drives us on, but it can also cloud our vision. The late physicist Joseph Weber argued for decades that he had observed gravitational waves with acoustic cylinders of his own making, and he adamantly defended those claims against overwhelming evidence to the contrary. Ultimately, that work was discredited, yet the concepts and equipment he developed serve as the basis for all gravitational wave detectors in use today.

We often make sharp distinctions between the sciences and the arts and humanities. Science aims at the external world of atoms and molecules, while the arts and humanities concern the internal world of emotions and sensibilities. Certainly, these distinctions are valuable as guiding principles, but in individual people, whether scientists or not, such neat separations do not occur. Nor in my view would they be desirable.

At its core, science is a human endeavour. Its strengths and flaws mirror our own. We should, of course, aspire to Feynman's advice, to accept nothing but the truth. But we also need to accept human beings in their totality, both as scientists and humanists, as objective and subjective, as dispassionate and passionate, as travellers in this strange cosmos trying to make sense of our world and ourselves. %s

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MA/PSC505

Manual

EDITED BY **Sophie Bushwick**

STATS

Time 8 hours
Cost \$70 (hand),
\$400 (control
board)
Difficulty
● ● ● ● ●

WAVE HELLO TO A SOFT ROBOT HAND

↓

In the field of soft robotics, engineers use squishy materials to make robots durable, flexible, and safer to operate around humans. Now intrepid DIYers can also bring life to squishy machines: Last September, Harvard University published an open-access Soft Robotics Toolkit online.

Some of the materials and skills Harvard recommends may be beyond the reach of a typical back shed roboticist. But with a little ingenuity, you can substitute cheaper parts and simpler techniques. This project makes actuated “fingers” out of ribbed hose from a cheap foot pump, long thin balloons (the type you can twist and fold into animals), and other basic items. By attaching five fingers to a

limb—in this case, a plastic gauntlet from a set of toy armour—you can form a robot hand.

Once you’ve assembled your appendage, it’s time for phase two of the project: building a fluidic control board. The Arduino brain controls and coordinates air valves to make the hand flash the peace sign, hang loose, or even flip the bird.

ANDREW TERRANOVA

137

Kilopascals
of pressure
required to
fully close the
robotic fingers

MATERIALS

- 10-mm inner diameter ribbed hose
- 8-mm wood dowel
- 5-mm outer diameter vinyl tubing
- Small hose clamps
- Five 5-mm hose barbs x 5-mm male threaded adapters
- Five 5-mm hose barbs x 5-mm female threaded adapters
- Electrical tape
- Yellow Teflon thread tape
- Several long balloons (type 350Q)
- 25-mm x 150-mm board or other support
- Fluidic control board

TOOLS

Utility knife



Spring-loaded centre punch

Drill press and 5-mm drill bit



Scissors



Flat-head screwdriver



Hot-glue gun



Measuring tape



Adjustable crescent wrenches

INSTRUCTIONS

1 Cut five finger-length pieces of ribbed hose. Notice the natural curl, and consider the upper side of the curve to be the “top” of each finger. Use a centre punch and drill press to make stress-relief holes along both sides of the hose, between each rib. Insert a wooden dowel to help support the finger’s shape while you do this.

2 Slice the top of each finger between each rib

from one side to the other, ending at the stress-relief holes. Now, each finger can curl more easily.

3 Use a dowel to insert a balloon into each finger. Secure the closed end of the balloon to the outside of the finger’s tip with electrical tape, and seal the tip with hot glue and more electrical tape.

4 Cut away the open ends of the balloons, leaving about 25-mm of

balloon beyond the end of each finger. Stretch the open end of the balloon out and over the end of each finger and secure with more tape.

5 Wrap the threads of each male hose barb with yellow Teflon tape and firmly tighten it into a female hose barb. Use more tape to wrap each female hose barb several times so it fits snugly into the open end of a finger. Secure it in place with the hose clamps.

6 Hot-glue the five fingers to the end of the board (or other support). This forms the hand. Finally, attach vinyl tubing to the open hose barb on each individual finger.

7 Now the hand is complete—but it still needs a control system. Hit up Google for a wide variety of Arduino sketches and detailed how-to videos. And don’t forget to scour the op-shops for old toys to give the hand some snazz.



THESE BOOTS WERE MADE FOR BOUNDING

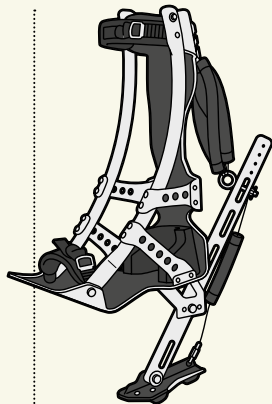
For 25 years, inventor Keahi Seymour has dreamed of running with the speed and loping gait of a much bigger animal. His inspiration struck at age 12, while he was watching a program about the kangaroo. "The announcer said it moves at such an efficient gait by using its Achilles tendons as springs," Seymour says. "I thought, 'Why not replicate that in a device that could propel a human?'" He began sketching footwear using ostriches as his model, because as bipeds, the birds run more like humans.

By the age of 17, he had built his first prototype using old Rollerblade boots, steel tubing, and bungee cords. Then, he built 200 more. Today, Seymour's Bionic Boot can propel him forward at 40 km/h. "You really feel superhuman," he says. Eventually, Seymour hopes to boost the speed to 65 km/h, perhaps by enhancing the boots' springy heels with electrical actuators. That, he expects, will take more than a few more prototypes. **ALISSA ZHU**



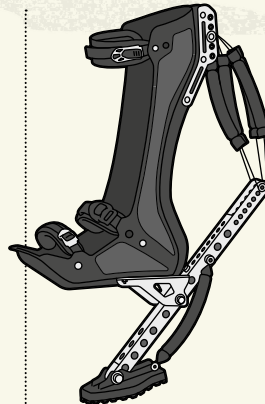
1998

Seymour made his third prototype from wire mesh and fibreglass, powered by an "Achilles tendon" made from steel tubing and a bungee cord spring. These boots were raised 25 to 30 cm above the ground, the height that later proved the most stable. But they only reached 25 km/h.



2010

To reduce the weight of subsequent prototypes from four kg to 2.5, Seymour swapped the fibreglass for aircraft-grade aluminium. He also replaced the springs, which had been made of thin rubber wound around a carabiner or a bolt, with thick rubber spear-gun tubing.



2012

Seymour ditched the all-aluminium boot in favour of a housing moulded from carbon fibre. To secure it to his legs, Seymour chose stable snow-board-boot clasps over lighter and flimsier Velcro fasteners. In later prototypes, he kept the carbon fibre but returned to Velcro, reinforcing it with nylon straps.

A Radio Built From a Junked TV

In Rebuild, columnist **Hackett** prepares for life after the apocalypse

↓
After the apocalypse, your big, fancy television will be dead—no power, no TV. So loot the corpse and use its parts to build the original broadcast entertainment: radio.

A radio transmitter sends information across a room, or an ocean, by creating a carrier wave of alternating current. Modulating the amplitude, or height, of that wave with an electrical signal (like the one produced by a microphone) encodes sound. Amplitude modulation (AM)

was the first radio broadcast method and is still in wide use.

To pick up radio waves, I needed a receiver to isolate the signal representing audio. I built a simple crystal radio from a hulking Zenith television I found on the street. First, the radio required an antenna—the larger, the better—so I harvested wire from the TV and ran it up two flights of stairs, out the window, and down the side of the building.

Next, I built a tuned circuit to match the frequency of the carrier wave from any given station. I coiled magnet wire from the Zenith's shielding shroud around a nonconducting centre—in this case, a beer bottle. Then, I sanded conductive points along the coil and rigged a movable connector. By changing contact points, I could change the length of the coil until I matched the desired frequency.

Pairing the coil with an adjustable capacitor made from tubes of tinfoil and paper strengthened the reception. I moved the tubes to adjust the radio's volume. The circuit then needed a diode—I found a geranium one in the TV's circuit boards. It changed the carrier wave into direct current, leaving the signal behind. Finally, a ground connection completed the circuit.

But I still needed a way to listen. Since the radio pulls electricity entirely from the radio waves, it didn't have enough power for normal headphones. A buzzer from a broken alarm clock did the trick, and I didn't mind the tinny sound.

I was somewhat shocked that the assembled radio worked. Next up is building a radio transmitter so when all media collapses, I'll be set to entertain myself.

4,705

Number of AM radio stations in the United States as of December 31, 2014

Repurposed Tech / That's a Job

HIJACK YOUR CAR'S INFOTAINMENT SYSTEM

As most drivers know, "infotainment" generally means "in-dash navigation system with limited function and old maps." Soup up your car's outdated software with an upgrade module and a powerful computer you already own—your smartphone. **MATT JANCER**

WARNING: Disconnect the car battery before installation, negative (black) terminal first. If you start sizzling, you've grabbed the wrong one.

MATERIALS

- Car
- VAIS Tech or Parrot kit
- Adhesive-backed Velcro
- Plastic or Velcro zip ties
- Smartphone

INSTRUCTIONS

- 1 The VAIS Tech kit (for Toyota and Lexus) uses the factory touchscreen, while Parrot's universal kit includes a separate screen. Both require you to remove the car's central dashboard panels.
- 2 Use adhesive Velcro to mount the kit's module well away from heating vents. Try putting it on the passenger side of the console, inside the console, or in the glove compartment.
- 3 Route the wires: Y-harness to the head unit, video harness to the touchscreen. Use zip ties to bundle these cables with the wiring behind your dash so they don't swing around.
- 4 To plug in your phone, run an AV cable and either a mini USB cable (for Android) or Lightning cable (for iPhone) behind the dash to the module. The flat type fits well between dash panels.
- 5 Program setup varies for different kits. Consult your car's manual, and follow the activation instructions. Then, reinstall the dashboard panels.
- 6 The new operating system borrows your phone's data connection to let the module's apps navigate, play music, and more.

STATS

Time 4 hours

Cost \$250+

Difficulty



Roller Coaster Designer

Structural engineer Alan Schilke specialised in designing supports for buildings and stadiums. Then one day, a roller coaster company asked him to create columns to brace its rides. When Schilke corrected the G-force calculations the company had been using for years, it hired him full time. Now, Schilke designs coasters for Ride Centerline LLC, drawing ideas from a lifetime spent soaring off BMX and ski jumps. **JUNNIE KWON**

How do you begin creating a new roller coaster?

I'm always thinking about what will make a coaster the most fun, which starts at the setup. In the X Games, they build 10 jumps in a row, but they're not all the same—they avoid repetition. That's the same thing you do when designing a roller coaster.



How does it feel to ride one of your own creations?

Back in the old days, I was always amazed. But today, we make simulations of everything. There are very few surprises anymore, because I've done it all virtually.

The Rattler was a 20-year-old wooden roller coaster at Six Flags Fiesta Texas in San Antonio. Schilke helped upgrade its tracks, transforming it into the wood-and-steel Iron Rattler, the first hybrid coaster to include a completely inverted barrel roll.

What are you working on now?

This year, we're converting two wooden roller coasters. We take an old, decrepit coaster that has outlived its life and put a steel I-box track on top of it, which upgrades it even beyond most modern coasters.

Even relatively modest lateral g-forces can provide hours of entertainment, as anyone at a theme park will attest. Spare a thought then for fighter pilots who train to withstand intense positive and negative gees. It's like having three of yourself standing on your head...

JAYCAR G-FORCE METER

Measure instantaneous G-forces from acceleration, braking, cornering or just getting sideways.

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www.jaycar.com.au

STATS

Time 1 hour

Cost \$49.95

Difficulty

• • • • •

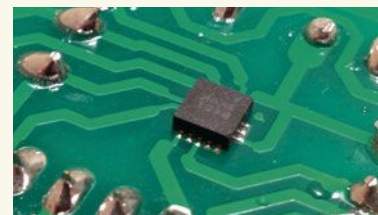
If you want an easy-to-build kit that lets you add an accelerometer to any vehicle, then Jaycar has you covered. Using an MMA8451Q accelerometer IC, it can track exactly how many gees you're pulling - up to positive or negative 2g. It's not just for car use either, and is battery powered and super portable.

The kit is actually a modified version of a Jaycar digital spirit level kit, using new software and a digital readout to display instantaneous acceleration.

The integrated circuit (IC) measures force with three tiny mechanical arms that bend and deflect in relation to each other. The arms form a capacitor, so as they bend under acceleration, the change can be read and used to calculate the g-force experienced. The IC used is actually similar to the accelerometer in many smartphones.

LINDSAY HANDMER

INSTRUCTIONS



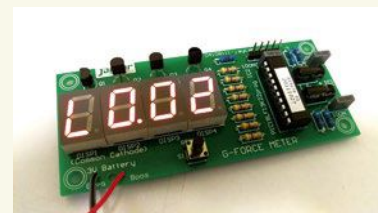
Step 1: The Kit

The accelerometer chip is tiny and surface-mounted, so fortunately for us Jaycar has already attached it to the underside of the circuit board. No mounting box is included, though there are instructions on how to build the kit into a jiffy box.



Step 2: Assembly

While the construction of the kit is fairly straightforward, it's important to ensure that the resistors are installed correctly. Some of the values have very similar colour schemes, so if in doubt, measure them with a multimeter before installing. Double-check the polarity of the power leads before powering it up, as there is no reverse protection. You can fry this little board pretty easily.



Step 3: In Use

When you first turn the kit on, it will simply measure the force of gravity (which is cool in itself) and needs to be calibrated. Place the unit on a flat surface and press the calibration button - the display should reset close to zero. If you then pick it up and wave it around, the display will read the highest g-force experienced, and display it for 5 seconds. Make sure you mount it solidly in your car to ensure accurate readings. We suggest the dash. Don't be disappointed though, if you think you're pulling hectic gravities but the unit reports a paltry 0.5g. It's amazing how strong even a little acceleration feels, when it's not in an everyday straight-down direction.

Go Ahead...

Ask Us Anything

Have a burning question?

Email it to askanything@popsci.com or tweet it to @PopSci #AskAnything.

ANSWERS BY **Daniel Engber**

ILLUSTRATIONS BY **Jason Schneider**



Q: DO BABIES EXPRESS EMOTIONS IN THE SAME WAYS ADULTS DO?

Short answer Eventually, yes.

A:

In 1986, psychology professor Linda Camras took a leave of absence from DePaul University to have a baby. For eight weeks, she recorded her daughter's every expression and what triggered it. "I did a lot of videotaping," she says. It was the first real-world test of a 1970s theory: that by two months old, babies automatically smile, knit their brows, and contort their faces to show positive versus negative emotions, like joy or fear.

The idea had made sense to Camras—until she started studying her own baby. "I found a lot of things that didn't fit into the theory," she says. For instance, her baby raised her eyebrows in a classic expression of surprise when playing with a familiar toy.

A baby's facial repertoire, Camras

observed, can be somewhat messy. Only with age and feedback does "it get organised so that there's a tighter link between the facial expression and the emotion," she says.

Michael Lewis, who studies child development at Rutgers Robert Wood Johnson Medical School, says, "Most people agree that by six to nine months, there are facial expressions of emotions." But he believes it occurs even earlier. His lab found that when infants as young as two months old pulled a string that cued up pictures of smiling babies and *Sesame Street* music, their faces showed pleasure. Later, when the string was disabled, they showed anger and sadness.

Camras, however, questions the assumption that a baby's face, unlike an adult's, always reveals its inner state. "If your professor slips and falls, you try not to laugh, because it's rude," Camras says. "As adults, we can control our facial behavior, but we assume babies don't do that."



Q: IS SECOND HAND VAPING HARMFUL TO YOUR HEALTH?

Short answer It's not as bad as second hand smoking.

A:

A small but disturbing study published last summer found that vaping indoors—even in a well-ventilated room—releases ultrafine particles and potentially carcinogenic hydrocarbons into the air. "Our data confirm that e-cigarettes are not emission-free," the authors wrote. Still, studies of exhaled vapour find that such emissions turn up at concentrations so low they may not pose much of a health risk to bystanders (or vapers).

The US Food and Drug Administration, which may be called upon to regulate e-cigarettes, remains cagey: "More data is needed to determine the constituents in e-cigarette aerosols and the potential risks of secondhand exposure." But Igor Burstyn, an occupational health expert at Drexel University, argues they're being overcautious. "It's propaganda mixed with willful ignorance," he says. "There are thousands of measurements from devices on the market." His 2014 e-cigarette data review concluded that contaminants "pose no apparent concern" to bystanders.

This we can say for certain: You're better off breathing in vapour than secondhand smoke. Tobacco smoke contains thousands of chemicals, 60 of them known carcinogens, says toxicologist Maciej Goniewicz. "In vapour, we find just a few of these, at much lower levels." **P**

MECHANICS · AUTOS · HOME IMPROVEMENTS

POPULAR SCIENCE

April 35c

MONTHLY

THE NEW TOOLS OF HOME DIY



In April 1956, *Popular Science* told readers how to modernize homes with bleeding-edge technology. The mark of a great home, we noted, “is not its size or shape or colour, but how much up-to-date machinery it has to make living easier.” At the time, that meant retractable electrical cords, smokeless ovens, and counter-top blenders. Today, that means something entirely different: app-based security systems, voice-controlled lighting, and cloud-based intelligence that learns your daily routine and adjusts the heat or AC to your liking—before you even walk in the door. To learn how to set up today’s smart home, turn to page 64.

JUNNIE KWON

359

Billions of US dollars Americans spent on home improvements between 2009 and 2011

48-PAGE HOME SHOW

10 Ways to Improve the Home You Have
A House Designed for Do-It-Yourselfers
What You Should Know About Appliances



**New Outdoor Room
You Can Build ... Page 148**

THE SMART HOME, CIRCA 1990

In 1990, Dutch astronomer Chriet Titulaer built his House of the Future, a US\$6-million mock-up of how we would live in 10 years. As *Popular Science* reported that September, it included state-of-the-art technologies—some of which took a little longer to come to fruition.

Personalised Security

From two metres away, the front door recognised the owner's unique chip card and automatically granted entry. How Elizabeth Shue!

Intelligent Fuel Indicator

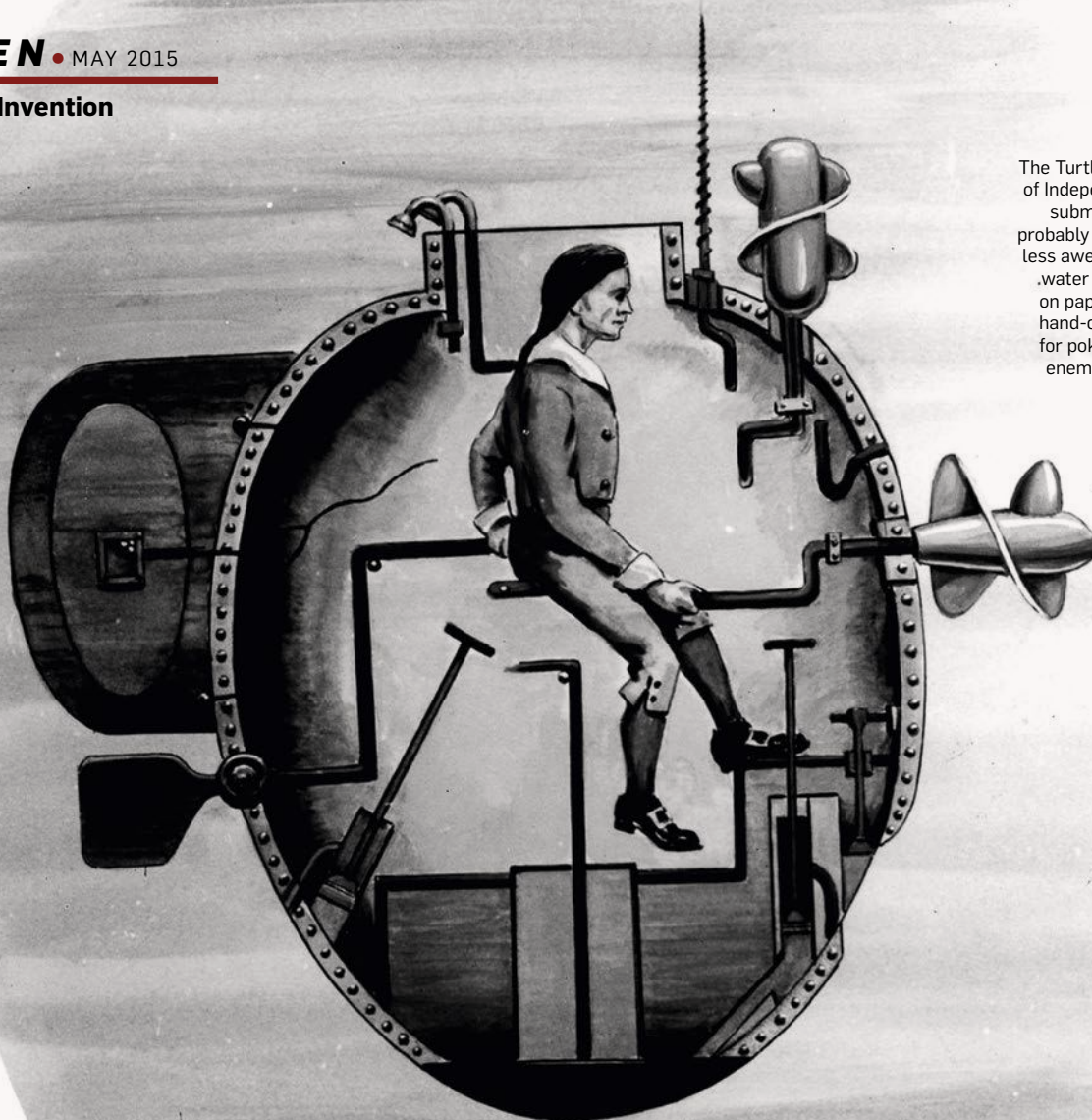
A sensor monitored gas consumption and used data such as indoor and outdoor temperature to help decrease utility bills. Smart meters!

Automatic Meal Delivery

A conveyor carried meals from the kitchen to a cube-shaped glass solarium near an ornamental pond outside. Very zen!

Virtual Chef

A central column in the kitchen housed a fridge, a freezer, food storage, and a computer that offered recipes onscreen or by voice. App-happy!



The Turtle: a US War of Independence era submersible that probably looked a lot less awesome in the water than it does on paper. Note the hand-cranked drill for poking holes in enemy ship hulls.

The Submarine

To independent senator John Madigan, submarines are the spaceships of the ocean. To us, they are the pinnacle of necessity being the mother of invention.

BY LINDSAY HANDMER



The first reports of submarines date back to the 1500, where the ancient Greeks experimented with submersibles. It wasn't until 1775 and the US War of Independence that the first military submarine was produced - the *Turtle*. The small lemon-shaped sub carried a single person and was powered by hand-cranked propellers. Just three metres long and 1.8m tall, the *Turtle* was built from wood, waterproofed with tar and reinforced with steel bands. It had a top speed of about 5km/h and carried enough air for just

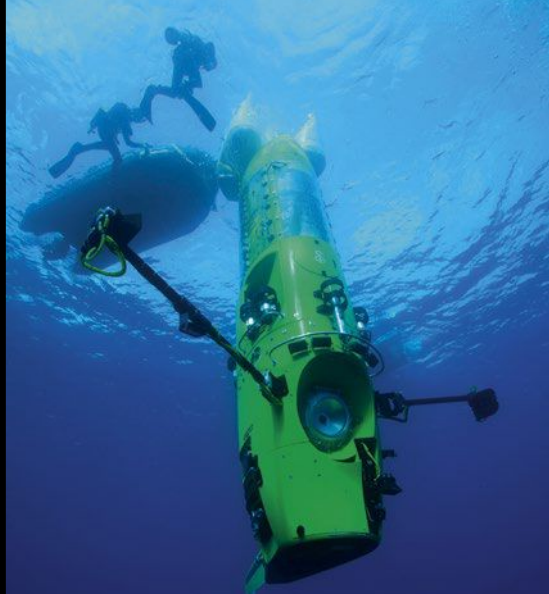
30 minutes of use.

It had small glass windows and used bioluminescent mushrooms (we aren't making this up) to light the instruments - though these stopped glowing if it got too cold.

In 1776, the *Turtle* was used in the first submarine attack, where it unsuccessfully tried to attach an explosive to the HMS *Eagle*. It wasn't until almost 100 years later that a submarine was built that did not rely on human power. The French *Plongeur* was launched in 1863 and ran from compressed air at 180 PSI.

The submarines that came after slowly began to resemble their modern counterparts - long and thin, with double hulls and ballast tanks.

In 1866 the first practical torpedo was developed, making submarines an effective weapon. The Whitehead

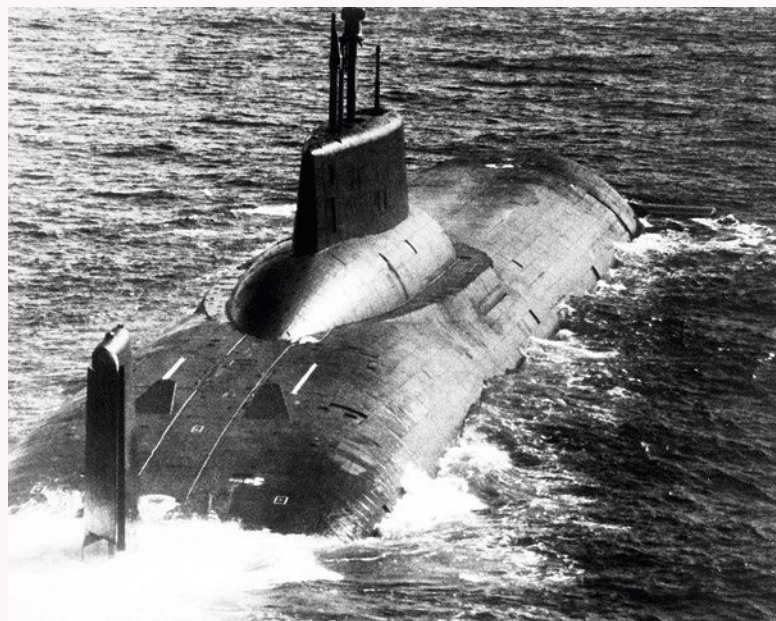


DEEPSEA CHALLENGER

Built in Sydney, the Deepsea Challenger is an ultra-deep-diving submarine designed to withstand the pressures of the deepest part of the ocean - the Challenger Deep at 11km. In 2012, film director James Cameron piloted the submarine, recording high resolution 3D footage of the ocean floor. Despite being 7.3 long and weighing 11.8 tons, the Deepsea Challenger only has room for a single occupant in a tiny 1m round pressure container. The Challenger Deep has only been visited by one other submarine, the Bathyscaphe *Trieste*.

THE COLLINS CLASS SUBMARINE

Constructed between 1990 and 2003, the six Collins class submarines are 77.42m long, weigh 3407 tons and can dive to 180m+. Powered by three 18 cylinder diesel engines coupled to generators, the main propulsion is provided by a single 5400 kW electric motor coupled to a 4.22m seven-bladed screw. The sub also has a 400 tonne lead acid battery pack that gives it an 890 km underwater range at 7.4 km/h. The subs are armed with a mixture of 22 torpedoes and anti-ship missiles. The Collins submarines suffered numerous setbacks (though now resolved), including poor welding and since-modified design that was noisy.



torpedo was powered by compressed air, had a 640m range and a top speed of 13 km/h.

In 1885 the first practical large steam-powered submarine was built - the *Nordenfelt I*. Weighing 56 tons and 19.5 meters long, the sub had a range of 240 kilometers and carried a single torpedo. A later sister ship, the *Abdul Hamid*, was the first submarine to fire a torpedo while underwater. Both these submarines shut down their engines to dive, running on stored steam pressure. It wasn't until the 1880s that electric motors and batteries made reliable and longer-range submarine propulsion possible.

These days most submarines are either diesel electric, or nuclear. Using an air-independent (that is, without needing to breathe air for combustion)

During the 1980s and 1990s, the oceans were full of massive submarines bristling with nuclear weapons capable of wiping out every major city in an afternoon. Good times.

propulsion method makes it possible for nuclear submarines to travel great distances underwater without ever needing to surface.

The largest nuclear-powered submarine ever built is the Russian Typhoon class, deployed from the 1980s. The Typhoons are 175m long, 23m wide and 12m deep. They are powered by twin OK-650 nuclear reactors, each generating 190 MW (254,800 HP).

The typhoon class subs carry nuclear ballistic missiles and are crewed by 160 sailors. The subs can reach a top speed of 27 knots (50 km/h) when submerged, can stay underwater for more than four months and can dive to 400m deep.

The Russians also built the fastest submarine in 1962 - the nuclear powered K-222. With an all-titanium hull (expensive!) the sub was 106.9m long and weighed 7100 tons. The K-222 had a top speed of 44.7 knots (82.8 km/h). Powered by two 177.4 MW nuclear reactors, it was used as a fast attack submarine to intercept aircraft carriers. ½

18

hours in the typical "submarine day" split into three blocks of six. Six hours on watch, six hours of sleep, and six hours spent studying, exercising, doing maintenance tasks and convincing Gene Hackman not to nuke Russia.



Next Issue

June 2015 - On sale 28th May

PLUS!

How to clone a **Mammoth** // Stem cell treatments that could **cure everything** // The **ethics** of self-driving cars // Fly the **SR-72** // Build a real-life **Tricorder** // **Hack** your fitness + **HEAPS MORE**

AN ENERGY REVOLUTION

Our current Commonwealth government seems to hate renewables, thinks wind turbines are ugly, and doesn't want to know about targets or change. But technology rolls on, anyway. We'll profile the biggest and most promising developments in energy tech, from molten salt reactors to rhubarb batteries, microhydro and more...

Floating wind turbines like this one take advantage of steady, constant winds at higher altitudes. They'll probably look really small from the ground. Your move, Mr Treasurer.



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